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EXPLANATORY NOTE.

With regard to the list of formations on page 21, and paragraphs 3 and 4 of page 27, Dr. Cotter states in a subsequent communication that the term "Eocene" has here been retained for this group in the sense in which Theobald used it, although it now appears proved that the basal beds of the group are older than Eocene and extend downwards into the Danian (Uppermost Cretaceous).

The *Cardita beaumonti* beds are Danian, but here there is no break between the Danian and the base of the Eocene.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME 72, PART 1.

THE GEOLOGY OF PARTS OF THE MINBU, MYINGYAN, PAKOKKU, AND LOWER CHINDWIN DISTRICTS, BURMA. BY G. DE P. COTTER, Sc.D., F.G.S., F.R.A.S.B. (With Plates 1 to 11.)

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FIG. 4.—Section due E.-W. through latitude 20° 54′, from Ngapyawa through Hni to the Nwamataung, in sheet 84 L/5. Scale 1 inch=1 mile. O. D. F.=Outer Dudawtaung fault. I. D. F.=Inner Dudawtaung fault.

FIG. 5.—Section through the northern part of sheet 84 L/5, from Ngapya through Tindu to the Nwamataung. Scale 1 inch=1 mile.

FIG. 6.—Section due E.-W. along latitude 21° 54′ in sheet 84 K/5. The section is drawn from the western margin (long. 94° 15′) to the eastern margin (long. 94° 30′). Scale 1 inch=1 mile.

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Fig. 2.—Section in a direction 10° south of east from a point $1\frac{8}{10}$ miles east by north of Wabin (a village in the centre of sheet 84 K/5), eastwards to a point $1\frac{3}{10}$ miles east by north of Ngangyaung in the same sheet. Scale 1 inch=1 mile.

Fig. 3.—Section from the Myittha valley eastwards, through Yama, Mawle, and Taunglon. Scale 1 inch=1 mile.

Fig. 4.—Section along latitude 22° 3′ 25″ in sheet 84 J/4 from the western margin of the sheet (long. 94° 0′) eastwards through the Myittha river just south of Pantoik village. Scale 1 inch=1 mile.

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THE GEOLOGY OF PARTS OF THE MINBU, MYINGYAN, PAKOKKU, AND LOWER CHINDWIN DISTRICTS, BURMA. BY G. DE P. COTTER, Sc.D., F.G.S., F.R.A.S.B. (With Plates I to II.)

CHAPTER I.

INTRODUCTION.

Area described.

The country with which this memoir deals lies between long. 95° on the east and long. 94° on the west. It is bounded on the south by lat. 20° 30′, and on the north by lat. 22° 15′. It lies mainly west of the Irrawaddy river and east of the Arakan Yoma and Chin hills, and includes the northern part of the Minbu district, (Salin and Sidoktaya townships), the greater part of Pakokku district. (Pauk, Seikpyu, Tilin, Gangaw, and Myaing townships), and parts of the Pale and Salingyi townships of Lower Chindwin.

Authors of geological map.

The geological survey of this tract was carried out by the following officers of the Geological Survey of India :—

G. de P. Cotter; seasons 1906-07, 1907-08, 1908-09, 1909-10, 1911-12, 1912-13, 1913-14, 1914-15.

Rao Bahadur, Sethu Rama Rau seasons 1907-08, 1908-09, 1909-10, 1910-11, 1911-12, 1914-15.

H. S. Bion, seasons 1911-12, 1913-14.

H. Walker, season 1915-16.
B. B. Gupta, seasons 1920-21, 1921-22, 1922-23.
E. L. G. Clegg, seasons 1921-22, 1922-23, 1923-24.
F. W. Walker, season 1922-23.
C. T. Barber, season 1925-26.
V. P. Sondhi, season 1926-27.

Three of these officers are deceased (Mr. H. S. Bion, Capt., F. W. Walker, M.C., and Rao Bahadur) Sethu Rama Rau; others are no longer on the active list, (myself, Mr. H. Walker, Mr. B. B. Gupta, Mr. C. T. Barber). I myself have perhaps had a longer connection with the survey of this area than any other officer, having spent eight field-seasons on it, and having afterwards been in charge of the party from 1921 to 1924, during which time I paid several visits of inspection to Minbu and Pakokku districts.

Mr. E. L. G. Clegg has also covered much ground in the country west of the Irrawaddy river. His work has been largely to the south of the country now being described. It has been arranged between us that Mr. Clegg should undertake the description of the southern area[1] (south Minbu, and Thayetmyo), and that I should describe north Minbu, Pakokku, and the southern portion of Lower Chindwin.

A sketch-map showing the positions of the Survey of India topographical one inch to the mile sheets, which cover the country now shown in the geological map accompanying this memoir, is given in the text-figure 1 on the next page.

Topographical maps.

The area under description was geologically surveyed by means of these maps on a scale of one inch to one mile. The sheets from north to south are numbered as follows:—

84 J/4, J/8, J/12, and J/16.
84 K/1, to K/16 inclusive.
84 L/1, L/5, L/9, L/13,
84 L/2, L/6, L/10, L/14.

Although this area has not been previously mapped as a whole in detail, several rough sketch-maps have been already published, and small portions of the area have formed the subjects of special papers.

Previous literature.

A list of literature dealing with the area is subjoined.

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[1] See *Mem. Geol. Surv. Ind.*, 72, Pt. 2, (in the Press).

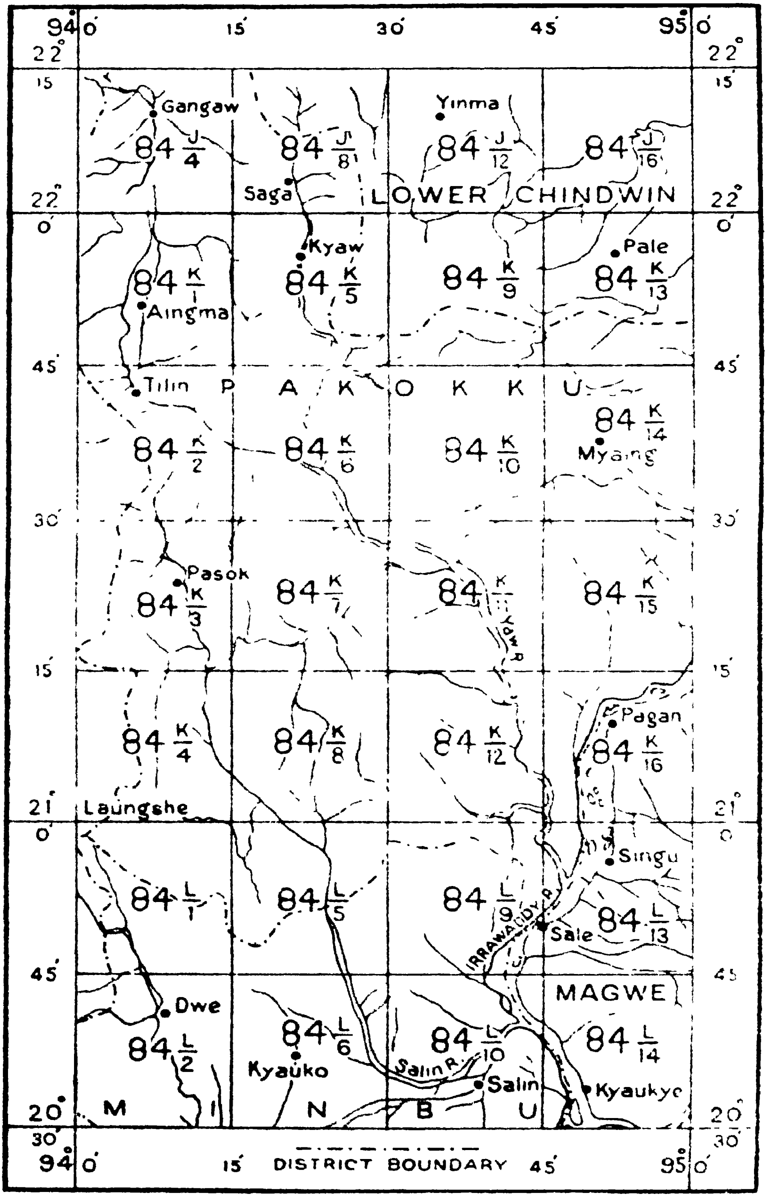

FIG. 1.—Map showing area discussed in the memoir.

List of previous papers and memoirs dealing with or referring to portions of this area.

1828.	BUCKLAND, W.	Geological Account of a Series of Animal and Vegetable Remains, and of Rocks, collected by J. Crawfurd Esq., on a Voyage up the Irrawaddi to Ava. *Trans. Geol. Soc. Lond.*, Ser. 2, Vol. 2.
1829.	CRAWFURD, J.	Journal of an Embassy from the Governor-General of India to the Court of Ava in the Year 1827, 2 vols.
1858.	OLDHAM, T.	Notes on the Geological Features of the Banks of the Irrawaddi, and of the Country north of Amarapura. Yule's *Mission to Ava*, Appendix A., pp. 309-351.
1873.	THEOBALD, W.	Geology of Pegu. *Mem. Geol. Surv. Ind.*, X, Pt. 2.
1894.	NOETLING, F.	On the Occurrence of Chipped Flints in the Upper Miocene of Burma. *Rec. Geol. Surv. Ind.*, XXVII, pp. 101-103.
1894.	,,	Note on the Occurrence of *Velates schmideliana* Chemn., and *Provelates grandis* Sow. in the Tertiary Formation of India and Burma. *Op. cit.*, XXVII, pp. 103-108.
1895.	,,	On some Marine Fossils from the Miocene of Burma. *Mem. Geol. Surv. Ind.*, XXVIII, pp. 1-45.
1895.	,,	The Development and Subdivision of the Tertiary System in Burma. *Rec. Geol. Surv. Ind.*, XXVIII, pp. 59-86.
1897.	,,	The Occurrence of Petroleum in Burma. *Mem. Geol. Surv. Ind.*, XXVII, pp. 47-272.
1897.	,,	*Hippopotamus irravadicus* from the Lower Pliocene of Burma. *Rec. Geol. Surv. Ind.*, XXX, pp. 242-249.

1898. Grimes, G. E. . Geology of Parts of the Myingyan, Magwe, and Pakokku districts. *Mem. Geol. Surv. Ind.*, XXVIII, pp. 30-71.

1901. Noetling, F. . Fauna of the Miocene of Burma. *Pal. Ind. N. S.*, Vol. I, Mem. 3.

1904. Gage, Lt. Col. A. T. The Vegetation of the District of Minbu in Upper Burma. *Rec. Botan. Surv. Ind.*, III, No. 1, pp. 1-141.

1901. Pilgrim, G. E. . Fossils from the Yenangyaung Oilfield, Burma. *Rec. Geol. Surv. Ind.*, XXXI, pp. 103-104.

1906. ,, . Fossils of the Irrawaddy Series from Rangoon. *Op. cit.*, XXXIII, pp. 157-158.

1906. Oldham, R. D. . On Explosion Craters in the Lower Chindwin district. *Op. cit.*, XXXIV, pp. 137-147.

1906. Pascoe, Sir E. H. The Assymetry of the Yenangyat Anticline. *Op. cit.*, XXXIV, pp. 253-260.

1906. ,, . The Northern Part of the Gwegyo Anticline. *Op. cit.*, XXXIV, pp. 261-265.

1907. ,, . Fossils in the Upper Miocene of the Yenangyaung Oilfield, Upper Burma. *Op. cit.*, XXXV, p. 120.

1907. Cotter, G. de P. . Note on the Tatkan Area. *Op. cit.*, XXXVI, p. 130.

1907. ,, . Fossils from the Miocene of Burma. *Op. cit.*, XXXVI, pp. 131-132.

1908. Holland, Sir T. H. General Report of the Geological Survey of India for the year 1907. *Op. cit.*, XXXVII, pp. 1-43.

1908. Pascoe, Sir E. H. . Marine Fossils in the Yenangyaung Oilfield. *Op. cit.*, XXXVI, pp. 143-146.

1908. ,, . On the Occurrence of *Batissa* in the Yenangyaung Oilfield. *Op. cit.*, XXXVI, pp. 143-146.

1908. Pascoe, Sir E. H. and Cotter, G. de P. A new species of *Dendrophyllia* from the Upper Miocene of Burma. *Op. cit.*, XXXVI, pp. 147-148.

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1909. Pascoe, Sir E. H. . Corrective Note on the Fossils described under the provisional name "Twingonia" from the Pegu Beds of Burma. *Op. cit.*, XXXVIII, p. 187.

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1910. La Touche, T. D. . General Report of the Geological Survey of India for the year 1909. *Op. cit.*, XL, pp. 73-122.

1910. Pilgrim, G. E. . Preliminary Note on a Revised Classification of the Tertiary Freshwater Deposits of India. *Op. cit.*, XL, pp. 185-205.

1910. Cotter, G. de P. . The Northern Part of the Yenangyat Oilfield. *Op. cit.*, XXXVIII, pp. 302-307.

1910. Stuart, M. . . The Re-correlation of the Pegu System. *Op. cit.*, XXXVIII, pp. 271-291.

1910. „ . . . Fossil Fish Teeth from the Pegu System, Burma. *Op. cit.*, XXXVIII, pp. 292-301.

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1912. Pascoe, Sir E. H. . The Oilfields of Burma. *Mem. Geol. Surv. Ind.*, XL, pp. 269.

1912. Cotter, G. de P. . The Pegu-Eocene Succession in the Minbu District near Ngape. *Rec. Geol. Surv. Ind.*, XLI, pp. 221-239.

1912. „ . Notes on some Nummulites from the Burma Tertiaries. *Op. cit.*, XLI, pp. 322-323.

1913. **Hayden, Sir H. H.** . . General Report of the Geological Survey of India for the year 1912. *Op. cit.*, XLIII, pp. 1-40.

1913. **Pilgrim, G. E.** . . The Correlation of the Siwaliks with Mammal horizons of Europe. *Op. cit.*, XLIII, pp. 264-326.

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1914. **Cotter, G. de P.** . . Notes on the Value of Nummulites as Zone Fossils. *Op. cit.*, XLIV, pp. 52-84.

1914. ,, . . Some Newly Discovered Coal-Seams near the Yaw River. *Op. cit.*, XLIV, pp. 163-185.

1915. **Middlemiss, C. S.** . . General Report of the Geological Survey of India for the year 1914. *Op. cit.*, XLV, pp. 85-137.

1916. **Hayden, Sir H. H.** General Report of the Geological Survey of India for the year 1915. *Op. cit.*, XLVII, pp. 1-41.

1916. **Pilgrim, G. E. and Cotter, G. de P.** Some Newly Discovered Eocene Mammals from Burma. *Op. cit.*, XLVII, pp. 42-77.

1916. **Holden, Miss R.** . . A Fossil Wood from Burma. *Op. cit.*, XLVII, pp. 267-272.

1917. **Hayden, Sir H. H.** General Report of the Geological Survey of India for the year 1916. *Op. cit.*, XLVIII, pp. 1-22.

1918. **Cotter, G. de P.** . . The Geotectonics of the Tertiary Irrawaddy Basin. *Journ. Asiat. Soc. Bengal*, New Ser., XIV, pp. 409-420.

1920. **Hallowes, Rev. K. A. K.** On the Coal-seams of the Foot-Hills of the Arakan Yoma, between Letpan Yaw in Pakokku and Ngape in Minbu. *Rec. Geol. Surv. Ind.*, LI, pp. 34-49.

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1927. Prashad, B. . . On some Fossil Indian Unionidæ. *Rec. Geol. Surv. Ind.*, LX, pp. 308-312.

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It will be seen that, of the papers listed above, only a very few deal with the detailed geology of the area now being described. Most of the papers are of a wide scope, and contain generalised descriptions of the oil-bearing tract of Upper Burma.

Unpublished progress reports.

The main source from which the material for this memoir is derived is the collection of progress reports of those officers who have partaken in the making of the geological survey of the area. As has been noted above, owing to the casualties which have occurred, it has been left to me and to Mr. E. L. G. Clegg to deal with the work of the Geological Survey of India in Burma since 1906; Mr. Clegg taking south Minbu and Thayetmyo district, and I taking north Minbu, Pakokku, and the southern part of Lower Chindwin.

CHAPTER II.

PHYSICAL FEATURES.

The fever-stricken Arakan Yoma hills which are aligned along the western margin of our map are yet of a memorable beauty.

General remarks.

I shall not forget the orchid clad trees of the Minbu Yomas, the shrill song of the cicalas, nor the scarlet blooms of the rhododendrons (*R. arboreum*) which cover the top of Mt. Victoria. The rains from the Bay of Bengal are held up by this mountain barrier, so that the eastern part of Pakokku and Minbu and the Myingyan districts are dry. There is therefore a strong contrast in climate. While the Irrawaddy valley in the east of the map is in the "dry zone" with a rainfall of 30 inches or less, the Arakan Yoma and the Pakokku Hill tracts have from 60 to 100 inches of rain, and on the Arakan coast the rainfall is nearly 200 inches.

Some of the rivers which drain these hills degenerate into meagre trickles of water in the dry season near their junction with the Irrawaddy. The bed of the lower Salin *chaung* is dry in the hot weather. The Yaw river dwindles at the same season to a thin trickle near Seikpyu. These are strong streams in the Yoma foothills, but their water is gradually absorbed by the porous Irrawaddy Sandstones, and dispersed underground.

The hills in the west of the map belong to the Arakan Yoma and to the Pakokku Hill tracts. The latter should be geographically grouped with the Chin hills. The dividing line between the Yoma and the Pakokku-Chin Hill area is fairly sharp. The Yoma is a single ridge dividing Arakan (Sandoway and Kyaukpyu districts) from Burma proper. This single ridge sends out on either side frequent transverse spurs. North-east of Sidoktaya, the single ridge of the Yoma is replaced by parallel and loftier chains of hills in northern Arakan and the Pakokku Hill tracts. West of Sidoktaya, the height of the Yoma ridge is from 6,000 to 6,500 feet (highest peak Suntaung 6,527 ft.); to the north in the Pakokku Hill tracts, about 11 miles west of Kanpetlet, Mount Victoria rises to 10,085 ft. above sea-level.

Arakan Yoma.

Parallel to this mountain-chain which divides Arakan from Burma, there are hill-ranges of lesser altitude. North-east and east of Sidoktaya the Nwamadaung range separates the valley of the Mon from the uplands which slope eastward to the Irrawaddy valley. Twenty-four miles north by east of Sidoktaya, another range, the Dudawtaung or Yeyodaung, intervenes between the Nwamadaung and the Irrawaddy valley. To the north the Nwamadaung, which attains a height of 3,073 feet in lat. 20° 55′, decreases in height, and ceases to be a dominant feature in the country east of Laungshe. The Dudawdaung continues northwards as a long narrow range, attaining a maximum height of 2,656 feet in lat. 21° 8′. Its height then decreases, and the range finally dies out south of the Yaw river.

Other hill-ranges.

Another range, aligned in echelon with the Dudawdaung, commences north of the Yaw river and is about 2 to 3 miles east of the longitude of the Dudawdaung. This is the Pondaung range. About lat. 21° 45′, the Pondaung range divides into two, and increases in altitude. Of the two ranges, that to the east is called the Pondaung, and forms the boundary between Lower Chindwin and Pakokku districts; that to the west is the Ponnyadaung. But a close examination of the map seems to indicate that the Ponnyadaung has more claim to be regarded as the true northward continuation of the Pondaung than the range to the east which bears the name of the Pondaung. I shall in future call this latter section of the Pondaung range the Northern Pondaung.

Pondaung and Ponnyadaung ranges.

The Northern Pondaung rises to over 4,000 feet in altitude; the greatest height marked on the map is in lat. 22° 4′, and is 4,364 feet above sea-level. The Ponnyadaung to the west is a lower range in the area mapped, but reaches the height of 3,464 feet in the extreme north. Further north beyond the mapped area, it rises to over 4,000 feet, the highest point between Upper Chindwin and Pakokku district being 4,442 feet.

The above are the main hill-ranges in the area surveyed, but there are many other hills and hill-ranges of less importance. Between the valley of the Salin *chaung* and the Irrawaddy river, there are uplands of low altitude near the Minbu-Pakokku border (Nalletaung, Yewegontaung), rising to a maximum of 1,536 feet about 20 miles south of Pauk. East of these irregular uplands and near the shore of the Irrawaddy river is the long range of the Yenangyat hills, the highest point of which, in the north of the field (Thagyi Taung), rises to

Lesser hills.

1,195 feet. This point is about 4 miles south of Magyithonbin village near milestone 25 on the Pakokku-Pauk main road. To the north this hill-range disappears owing to the general rise of the surrounding country to an altitude of about 1,000 feet. Further north, about 16 miles W. N. W. of Myaing, this line is continued by another range called also Thagyi Taung (altitude 1.769 feet); this passes northwards into the Shwetagyitaung, which rises to over 2,000 feet in height. Another low range, the Pagyidaung, lies to the north-east of the Shwetagyitaung.

Myaing, Pagan, and Gwegyo hills.

Mahudaung.

There are some isolated hills north of Myaing, and also across the Irrawaddy, south-east of Pagan, the Pagan hills with their southward continuation, the Gwegyo hills, which lie partly on, and partly eastward of, the south-eastern margin of the map. In the north of the map, the Khode Taung and the Satha Taung (2,105 feet) are the southern terminus of a range of some importance in the territory north of the map, *i.e.*, the Mahudaung. East of this the Pindaungtaung is a low ridge some 13 miles long, the highest point of which is 1,760 feet.

The lowest part of the area mapped is the Irrawaddy river which near Yenangyaung is about 150 feet above sea-level. The drainage of Pakokku and Minbu districts falls entirely into the Chindwin or Irrawaddy rivers.

Irrawaddy and Chindwin rivers.

Much has been written regarding the ancient course of the Irrawaddy river.[1] The general opinion of geologists is that the Upper Irrawaddy originally flowed down the valley now occupied by the Rangoon-Mandalay railway, but that, owing to earth-warping, the river broke through to the westward at Sagaing, and fell into the Chindwin, which originally occupied the valley now carrying the united flow of the two rivers from Pakokku to the sea. Sir E. H. Pascoe also thinks that the ancient Chindwin may have included the head-waters of the Brahmaputra, and although this theory needs further field-work to substantiate it, it is nevertheless obvious from the work of Prof. Gregory and others[1] that considerable alteration in river-courses has taken place since the commencement of Pleistocene times in India.

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[1] This question appears to have been discussed first by J. M. Maclaren [*Geogr. Journ.*, XXX, pp. 507-511, (1907)], and is further dealt with by J. Coggin Brown [*Rec. Geol Surv. Ind.*, XLIII, pp. 178-180, (1913)]. Sir E. H. Pascoe [*Mem. Geol. Surv. Ind.*, XL, Pt. 1, p. 255, (1912)] thinks that the primitive Irrawaddy followed the course of the Chindwin and included the head-waters of the Brahmaputra; while J. W Gregory [*Geograph. Journ.*, LXI, p. 166, (1923)] thinks that besides the primitive Irrawaddy of Pascoe following the course of the Chindwin and Lower Irrawaddy below Sagaing, another river, that is the upper Irrawaddy above Mandalay, flowed down in a parallel course through the present valley in which the Rangoon-Mandalay railway is aligned, past Meiktila and Pyinmana.

The entire drainage of the area now mapped falls into the Chindwin or the Irrawaddy river. There are two other rivers of major importance and with perennial water; these are (1) the Yaw, and (2) the Myittha with its tributary, the Maw.

Maw and Myittha rivers.

These two rivers follow mainly the synclinal axes of folds. This is especially noticeable in the case of the Maw-Myittha. The Maw rises in the country south of Tilin, and joins the Myittha, about 22 miles north of Tilin. The river continues northwards for about 80 miles and at Kalemyo in the Upper Chindwin district, it turns sharply to the east, crossing the northward continuation of the Ponyadaung range, and finally falls into the Chindwin at Kaleywa. The Myittha rises in the Chin hills, west of the area now being dealt with. The Maw, and the Myittha below its junction with the Maw, to Kalemyo, follows a synclinal axis, and then, between Kalemyo and Kaleywa, becomes a transversal stream, probably breaking through a saddle in the anticlinal fold, although this opinion requires confirmation by further detailed work.

Yaw river.

The Yaw river rises in the Pakokku Hill tracts north of Kanpetlet, and follows an irregular course through the monoclinal belt east of the Pakokku Hill tracts, being joined at Hnetchaung by the Saw river from the south, the latter having its source in the hills south of Kanpetlet. The Yaw river now skirts the southern termination of the Pondaung range, and flowing north-east over easterly dipping strata to Pauk, turns south-south-east along the synclinal axis between the Yenangyat hills and Pondaung and Dudawdaung ranges, and reaches the Irrawaddy, still keeping west of the Yenangyat hills.

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[1] *See* 'Pleistocene Movement in the Indian Peninsula' by E. W. Vredenburg, *Rec. Geol. Surv. Ind.*, XXXIII, pp. 33-45, (1906); also the chapters on 'The Rivers of the Himalaya and Tibet' in 'A Sketch of Geography and Geology of the Himalayan Mountains and Tibet' by Sir S. G. Burrard and Sir H. H. Hayden, pp. 119-208, Calcutta (1907).

The following papers may also be consulted: Pilgrim, G. E., 'Suggestions concerning the History of the Drainage of Northern India arising out of a Study of the Siwalik Boulder Conglomerates,' *Journ. As. Soc. Beng.*, N. S., XV, pp. 81-99, (1919); Pascoe, Sir E. H., 'The Early History of the Indus, Brahmaputra, and Ganges', *Quart. Journ. Geol. Soc.*, LXXV, pp. 138-157, (1919).

The alignment of the two rivers described is clearly resultant upon the geological structure; their courses follow the synclines and when crossing the lines of anticlinal folds, choose the saddles or skirt the terminations.

Salin river.

The southern part of the area is drained by the Salin river, which rises in the hills west of Laungshe, and, breaking across the Yeyodaung range, traverses the Irrawaddy sandstones in a broad semicircular sweep past Salin and Sinbyugyun to the Irrawaddy.

Yama rivers.

In the north-east of the area mapped, the Yama stream drains country mainly of soft Irrawaddy sandstone. Another Yama stream south of Pale drains a similar type of country of Irrawaddy sandstones and alluvium.

Flora and fauna.

These are the principal rivers of the area; the Myittha, Maw, and Yaw are perennial streams; the Salin river is dry in the hot weather in its lower reaches; the Yama streams are dry generally except during the rains or after heavy rain. This memoir is not concerned with the flora and fauna of the area, except in so far as they bear upon the geology. Yet there are some interesting features which should not pass unnoticed.

The flora of Minbu district has been described by Col. A. T. Gage[1], who divides it into three zones, (1) that of the Arakan Yoma and Nwamataung ranges; (2) that of the desert zone; and (3) that of the alluvial belt. Of the desert zone he remarks:—

> 'The most striking feature, however in the vegetation of this zone is the preponderance of Deccan and Indo-African species. This preponderance is no doubt exaggerated in the table based on this collection only, but the two elements together probably form at least about a fourth of the whole vegetation of the zone, contrasting strongly with the meagre show they make in the other two zones. How to account for the presence of such a comparatively large percentage of Indo-African species is an interesting problem. One knows that the presence of a considerable African element in the Indian peninsula is explained by the existence of a land-connection with Africa in pre-tertiary times. Whether one can suppose the existence of a similar land-connection between Upper Burma and the Western Peninsula before the formation of the Arakan Yomas in tertiary times is a question for geologists to settle.'

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[1] The Vegetation of the District of Minbu in Upper Burma, *Rec. Bot. Surv. Ind.*, Vol. III, No. 1, (1904).

Sir E. H. Pascoe[1] accepts the view that the Gondwana continent extended from India to Burma, as well as to Australia and Africa. He accepts Col. Gage's work as evidence that in former times the Gondwana continent included Burma as well as India and was bounded on the north and east by the Tethys sea.[2]

The relationship of the flora to the underlying rocks has been discussed in detail by L. D. Stamp and Leslie Lord,[3] whose results are briefly as follows :—

I. Irrawaddian Sands and Gravels.

In the south of Burma, south of Thayetmyo, *Tectona grandis* is common, but as the rainfall diminishes, *i.e.*, as we move northwards into the dry zone, this gives place to a forest of *Dipterocarpus* and *Pentacme*. The species are Eng or *Dipterocarpus tuberculatus* and Ingyin or *Pentacme suavis*. The Eng forest seems to thrive on almost pure sand, but as the rainfall drops below 34 or 35 inches, Eng is replaced by Ingyin, and this in turn by *Diospyros birmanica* and *Terminalia tomentosa*. In this very dry type of forest, *Acacia catechu* and *Tectona hamiltonii* are numerous, these last two species increasing in importance to the north, and giving rise to the Sha-Dahat forest. Finally in the semi-desert, we find a thorn scrub of stunted *Acacia catechu* and *Euphorbia antiquorum*.

Where the Irrawaddian is obscured by alluvium, *Zizyphus jujuba* is common. The vegetation is more varied near stream-courses.

II. Pegu Sands and Loams.

Bamboo (*Dendrocalamus strictus*) is abundant. In the country north of Thayetmyo Ingyin (*Pentacme suavis*) is common, also *Diospyros*. Northwards from Minhla, the large quantity of gypsum in the clay bands has a deleterious effect, and the *Acacia-Tectona* Thorn Forest prevails. In the driest parts, even thorn scrub of *Acacia* and *Euphorbia* is found.

III. Pegu Clays.

In south Thayetmyo these clays produce a Bamboo-*Acacia* Savannah Forest. There are dense bamboos, and scattered larger trees, *Terminalia bialata*, *Acacia catechu*, and *Zizyphus jujuba*. Further to the north-west, where the surface drainage is good, a *Tectona hamiltonii-Terminalia oliveri* Savannah Forest is typical. Where drainage is bad, there is *Acacia catechu* Thorn Forest.

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[1] *Mem. Geol. Surv. Ind.*, XL, p. 248, (1912).

[2] Sir E. H. Pascoe's account in the passage quoted does not appear to require a belief in the theory of continental drift. He follows Burrard and Hayden [Sketch of the Geography and Geology of the Himalaya Mountains and Tibet, Calcutta, (1907-1908)] in the main. I have in a recent paper [Geological Structure and Distribution of the Oil-bearing Rocks of India and Burma ; *World Petroleum Congress*, London, (1933), paper No. 168] advocated the continental drift theory as applied to India, and I agree with Sir E. H. Pascoe that Burma as far east as the western margin of the Shan States formed part of Gondwanaland.

[3] The Ecology of part of the Riverine Tract of Burma, *Journ. of Ecology*, Vol. XI, pp. 129-159, (1923).

IV. Stream alluvium and hill-wash.

On this land, much of which is cultivated, is found *Zizyphus* with (in the south) bamboo, and with (in the north) the wild Castor (*Ricinus communis*) or with several species of *Jatropha*. Where there is good drainage, the hedgerow vegetation characterised by *Combretun apetalum* is found.

V. Alluvium of the Irrawaddy river.

Cultivated land, but characterised by " Kaing " grass (*Saccharum spontaneum* and *S. fuscum*). There are large shady trees, mostly planted Tamarind (*Tamarindus indicus*), Toddy Palm (*Borassus flabellifer*), and Cotton Tree (*Bombax malabaricum*).

The above classification, although applied by L. D. Stamp and L. Lord to the country between Yennangyaung and Prome, will apply equally well to the drier parts of north Minbu and Pakokku. In the more rainy belt to the west is found a more luxuriant forest, and on the banks of the Myittha in the Chindwin districts, the forest somewhat resembles that of Tenasserim, owing to the abundance of tall trees (teak, *Xylia*, *Terminalia*, *Dipterocarpus*), and in the wetter parts abundant *Calamus*.

Mount Victoria is clad from 9,000 feet or so upwards with Rhododendron forest. The Rhododendron trees are of one species (*R. arboreum*) with scarlet flowers, making a fine show in the spring. There are however smaller species of Rhododendron (*R. formosum*) in the undergrowth. This last has white flowers.

Below the Rhododendron belt is a mixed forest, in which *Pinus khasya* predominates. There are species of *Quercus*, and many other trees (*Castanopsis*, *Cedrela*, *Dipterocarpus*).

The fauna of the area need not concern us here, but it may be remarked in passing that zoologists have supposed a former land connection between Malaya, India, and Madagascar, this former continent being termed " Lemuria ".[1] It has been thought that the existing distribution of animals and especially of lemurs can best be accounted for by this theory. Those who believe in the theory of continental drift, will regard " Lemuria " as merely a large fragment of Gondwanaland, after South America and Australia had broken away.

Additional evidence of a former land connection between Madagascar and India is brought forward by Baron von Huene and Dr. C. Matley in their account of the reptiles from the Upper

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[1] *See* A. Geikie, Text-Book of Geology, 4th edition, (1903), p. 391, and references.

Cretaceous of the Central Provinces[1], but in Burma there are no Mesozoic reptilian remains as yet discovered.

The connection of the Indian mammalian fauna with that of Africa is clearly proved by a comparison of late Tertiary Indian forms with existing African fauna. The Burma tertiary mammalian fauna may perhaps be regarded as belonging to the same province.

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[1] The Cretaceous Saurischia and Ornithischia of the Central Provinces, *Pal. Ind.*, N. S., Vol. XXI, (1933).

CHAPTER III.

THE AXIAL GROUP.

List of formations.

The following is a list of the formations met with, with their approximate European equivalents :—

6. Low level Alluvium			Sub-recent to Recent.
5. High level Alluvium, and Plateau Gravel			Pleistocene.
4.*b*. Irrawaddy sandstones			Pliocene to Pontian, or Vindobonian in north.
4.*a*. Maw gravels and sands			Pontian to Vindobonian or Burdigalian.
3. Pegu series—			
	Upper	Akauktaung stage	Vindobonian.
		Pyalo stage	Burdigalian.
	Middle	Kama stage	Aquitanian.
		Singu stage	Chattian.
	Lower	Padaung stage	Stampian.
		Shwezetaw stage	Lattorfian.
2. Eocene series—			
	Upper	Yaw stage	Priabonian.
		Pondaung stage	Auversian.
	Middle	Tabyin clay	Lutetian.
		Tilin sandstone	Lutetian.
	Lower	Upper Laungshe beds	Ypresian.
		Lower Laungshe beds	Thanetian.
		Basal Laungshe beds	Danian.
1. Axial rocks and Kanpetlet schists			Age unknown, probably in the main pre-Cambrian but with infolded rocks of Mesozoic age.

It will be convenient to discuss these formations in an order reverse to that given in the above list, that is, commencing with the oldest.

I. THE AXIAL GROUP AND THE KANPETLET SCHISTS.

It will be seen from the map that the most westerly rocks along the slopes of the Yoma and the Pakokku Hill tracts are labelled Axials.

History of term "Axial".

This term needs clarification, and I must recount its history and try to give a clearer definition of its meaning than it formerly possessed.

The term was first used by W. Theobald [1], who applied it to the altered rocks which constitute the main range of the Arakan Yoma. Later Theobald [2] restricted the term to certain rocks in western Thayetmyo which he imagined to be of Triassic age, while those to the south in Western Prome and in Bassein district he termed Negrais series, with a hint that they were of later age, perhaps Cretaceous.

There is not much fossil evidence for regarding the Negrais rocks as Cretaceous. The rocks are, according to M. Stuart,[3] a monotonous series of indurated sandstones and shales. Stuart includes in this term all sub-metamorphosed rocks which form the high land of the Yoma.

> 'The only fossils', says Stuart, 'which have been obtained from them are a few badly preserved specimens of what appear to be a species of *Vicarya* preserved in iron pyrites, which I obtained from a shaly bed some nine miles west of Myinwadaung.'

Negrais rocks.

The Negrais rocks must be regarded as older than Eocene, in spite of the *Vicarya*-like shell, as they appear to underlie the Eocene all along the southern Arakan Yoma.

In the Andaman Islands, Mr. G. H. Tipper [4] found sedimentary rocks underlying the Eocene. They consisted of red and yellow jaspers, quartzites, and pink and white porcellanic limestones. He regards the porcellanic limestone as very similar to the Lower Cretaceous limestones of Baluchistan. This series is associated with serpentine. Mr. Tipper remarks that these rocks are similar to those of the Arakan Yoma and of Manipur.

At Kywezin in Henzada district, M. Stuart describes certain coal-seams which lie on the boundary of the Eocene and Negrais series. He places this coal in the basal Eocene, but subsequently Mr. C. Beadon found a fossil fragment in this coal, apparently of an ammonite.[1] This specimen in two pieces was sent to Dr. L. F. Spath, British Museum, for examination. He has sent the following note on the specimen.

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[1] The Axial Group in Western Prome, *Rec. Geol. Surv. Ind.*, IV, p. 33, (1871).

[2] Geology of Pegu, *Mem. Geol. Surv. Ind.*, X, (1873).

[3] Geology of Henzada, *Rec. Geol. Surv. Ind.*, XLI, p. 240, (1912).

[4] *Mem. Geol. Surv. Ind.*, XXXV, p. 205, (1911).

> 'The two specimens you forwarded proved to be parts of one individual and at first seemed quite unidentifiable. After a good deal of hesitation, I have, however, now come to the conclusion that the specimen is neither a *Perisphinctes* nor even Jurassic, but (if a cephalopod at all) must be one of those turricones that are commonest at the top of the Campanian and especially the base of the Maestrichtian, and that it probably belongs to the genus *Bostrychoceras*. It is, in fact, comparable to the type species of *Bostrychoceras* itself, namely *B.* ("*Heteroceras*") *polyplocum* (Schluter) which may or may not have tubercles, but in the absence of a suture-line and in view of the generally poor condition of the specimen, this identification cannot be more than provisional.'

Mr. A. Campbell informed me that other coalseams occur on the western side of the Yoma in the Bassein district.

Theobald describes the Negrais rocks as shales and sandstones, generally highly altered, the sandstone being converted into a cherty rock. There is widespread alteration both of sandstones and of shales. He mentions the presence of blue slaty shales with interbedded blue limestones unfortunately unfossiliferous. On the axis of the range he found reddish and pink clays. He mentions a sandstone series exposed on the coast, which appears to rest with a basal conglomerate upon the more highly disturbed Negrais rocks. He includes this sandstone in the Negrais group, but, if so, the Negrais groups must be a complex including rocks of very different ages. At Cape Negrais he notes the presence of crushed carbonaceous tree trunks and branches in the shale and sandstone series.

Our knowledge of the Negrais group is so scanty that only the vaguest conjecture can be made of the age. The coal-measures of Kywezin appear, if Dr. Spath's provisional identification be accepted, to be Upper Cretaceous. But Dr. M. Stuart places these coal-measures in the base of the Eocene, and not in the Negrais group. It will be seen from the notes given in a later page on the country to the north from Thayetmyo to Pakokku, that there is good ground for supposing that the Burma Eocene series extends downwards into the Upper Cretaceous. Dr. Stuart's view that these coal-measures are to be grouped with the Eocene suite rather than with the Negrais is not inconsistent with recent results.

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[1] *See* The Mineral Deposits of Burma, by G. de P. Cotter, Government Printing Press, Rangoon, (1924), p. 18.

Negrais group a complex.

If we remove these coal-measures from the Negrais group, actual fossil evidence as to the age of the group is practically absent. One has a strong impression that we are dealing with a complex of several rock-groups, and not with rocks entirely Cretaceous, or entirely belonging to any other period. Perhaps the *Vicarya*-like shell found by Dr. Stuart may represent an infold of Tertiary rocks; or the shell may be one of those Cretaceous gasteropods, *e.g.*, *Trocalia*, similar to forms found associated with the Axials in Pakokku (*vide infra*). It is clear however that the Negrais group is for the most part completely unfossiliferous. The probability is that we are dealing with ancient unfossiliferous rocks, isoclinally folded, into which are infolded bands of fossiliferous rock of Mesozoic or later age.

In the single section accompanying Theobald's memoir, he shows that the structure through the Arakan Yoma to the Irrawaddy between Kama and Prome is isoclinal throughout the Yoma until the boundary of the Nummulitics is reached.[1]

Ma-i group.

The Ma-i group of Theobald is founded upon the discovery of a single specimen of *Inflaticeras* in the bed of a small stream near Ma-i in Sandoway district. Theobald supposes that it had weathered out of the shales exposed in the stream-bed. Upon this evidence, Theobald has marked a very large portion of the western slopes of the Arakan Yoma as Cretaceous, but it is not necessary to suppose as Theobald does that the Cretaceous rocks extend inland into the heart of the Yoma. A Cretaceous fossil (*Mammites daviesi*) has been recorded from Ramri Island.[2] This seems to indicate that the Cretaceous rocks are striking in a north-north-westerly direction along the Arakan coast.

Central Yoma Eocene an error ?

With regard to a belt of Eocene rocks mapped by Theobald immediately west of the Yoma ridge in Sandoway district, and shown on the new geological map of India, I can find no evidence in his text, and I am inclined to think that this is a cartographic error which was made when reproducing Theobald's original map.

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[1] *Mem. Geol. Surv. Ind.*, X, Pl. 1, (1873)

[2] *Op. cit.*, XXI, p. 48, footnote, (1884); and *Rec. Geol. Surv. Ind.*, LXVI, p. 255, (1932), and LXVIII, p. 414, (1935).

The belt is not shown in his section above mentioned. The only Eocene rocks he mentions west of the Yoma are those on the coast from Kyeintali (" Kyeantalee ") northwards. The view that this central Yoma strip of Nummulitic rocks is a cartographer's error seems proved by the remark in Theobald's memoir (p. 318) :—

> 'On the East, the Axials are in immediate contact with the Nummulitics, the beds of both groups standing at a high angle. On the West in place of the Nummulitics, there is a great thickness of rocks of undoubtedly Cretaceous age.'

If the strike of Theobald's Negrais group is continued northwards, it will readily be seen that these rocks strike into the Axial group. But Theobald marks a faulted boundary between the two, at the same time marking the boundary on his map " unsurveyed ". He has also the following remark in his memoir (p. 316) :

> 'I am aware of the well-founded and laudable jealousy which exists in the minds of many geologists touching the introduction of faults which are incapable of ocular demonstration ; but it is possible to carry this to the opposite extreme, etc.'

Theobald's fault between the Axials and the Negrais groups is therefore hypothetical, and we are not bound to accept it as it is not based upon field evidence

On the contrary, we have seen that the Negrais group is in all probability a composite one of several ages, and not necessarily Cretaceous. I shall show now that Theobald's belief that the Axials were Triassic involves the same fallacious narrowing down of the age of a composite group to that of a single fossiliferous limestone band infolded in it.

Axials of Thayetmyo a complex group.

Theobald (p. 321) gives a section through the Axials in the Hlwa stream in western Thayetmyo. The general type of sub-metamorphosed sandstones and shales does not seem to differ sufficiently from the Negrais type of rock to justify a separation on lithological grounds. On the contrary the lithological similarity to the Negrais group and to the pre-Tertiary rocks of the Andamans described by Mr. G. H. Tipper is rather striking. Normally, their similarity, the fact that they are on the same strike, and below the same Tertiary suite of rocks would lead us to conclude that they are closely related.

Theobald's section in the Hlwa stream is thus epitomised by him (p. 322):—

	Ft.
Lower Axial Shales and sandstones	300
a. Cardita shales	110
b. Halobia limestones, shales, etc.	33
c. Freckled grits, etc.	1,364
d. Shales and sandstones	1,221
e. Shales and sandstones	976
f. Sandstones, etc.	147

The whole section is regarded by Theobald as in normal ascending order. Strata *a* to *f* are marked "Upper Axials".

Mr. G. H. Tipper in two notes on the "Trias" of Lower Burma[1] has cast a spanner into the mechanism of Theobald's reasoning. Theobald's *Cardita* beds are shown by Mr. Tipper to contain *Venericardia beaumonti*, the well known Danian fossil of North-western India. In the *Halobia* beds, which are truly Triassic, *Halobia lommeli* occurs, with *Monotis* and *Avicula*. Mr. Tipper says in conclusion:—

> 'It is very evident that Theobald's Axial (Triassic) group is a very mixed one, containing not only Triassic rocks, but also beds of Cretaceous age.'

Obviously the *Cardita* beds are infolded into older rocks, the whole being more or less isoclinally folded. There is also obviously no reason to suppose, because the *Halobia* beds are Triassic, that the entire mass of unfossiliferous Axial beds are also Triassic. Such an argument from the particular to the general is unsound.

Axials and Negrais the same.

The time is now ripe for a reconsideration of the whole question. It must be concluded that (*a*) the distinction between the Negrais and Axial rocks is very doubtful; (*b*) both are complex groups, comprising rocks of different ages; (*c*) the strip of Eocene rocks mapped in the central Yoma area is probably a mistake; its existence is certainly very questionable; (*d*) Cretaceous rocks of Albian to Turonian age occur at Ma-i on the coast and in Ramri Island on the same strike, but there is no justification for marking the Cretaceous belt as extending so far inland as Theobald has done.

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[1] *Rec. Geol. Surv. Ind.*, XXXIV, p. 134, (1906), and XXXV, p. 119, (1907).

Chin shales.

F. Noetling, who in many other instances has changed the pre-existing names given by earlier geologists to Indian formations[1] without any very obvious cause, has complicated the definition of the Axial group by the introduction of a new name 'Chin shales' for the pre-Tertiary rocks of the Yoma.[2] We may at once dismiss this term to the waste-paper basket.

Sir H. H. Hayden, under Noetling's term 'Chin shales', describes the Yoma rocks underlying the Tertiaries in Minbu district.[3] The rocks found consisted of (1) a bed of very dark purple schist with some limestone bands, (2) an immense thickness of green and purple shales containing enormous quantities of vein quartz, (3) intrusions of dolerite, gabbro, and serpentine. There is intense crushing, folding, and faulting.

Turning now to the area shown in the map accompanying this memoir, it may be observed that no fossils are known with certainty from these Yoma rocks; some Upper Cretaceous fossils, found on the margin of the Axials in Pakokku, are doubtless referable to the basal beds of the succeeding series (Eocene group).

The *Cardita beaumonti* beds of the Hlwa stream in Thayetmyo district must, I think, also be referred to the Eocene group, which extends downwards into the Danian.

Some *Globigerina* limestone of unknown age occurs in the Minbu Axials, and there are no other known fossils in the series save those above noted.

Axials of north Minbu.

The country from Sidoktaya to Saw was mapped by Mr. E. L. G. Clegg. The following account of the north Minbu Axials is taken from his progress reports on the area :—

The Axials west of Sidoktaya consist of shales, schistose sandstones, schists, and lavas. The occurrence of these lavas lying in big blocks upon sandstones recalls the structure of pillow lavas, but no section was found which was decisive enough to settle the question whether they are really pillow lavas or not.

The lava is of a vesicular type with greenish glassy appearance. Under the microscope, aggregate polarisation is shown under crossed nicols. The vesicles, which are rounded, are filled with calcite, and other parts of the section show impregnation by the same mineral. Towards the edge of the slide, a mosaic of quartz seems to form the ground-mass, although in ordinary light a large quantity of a greenish mineral has the outlines of what were apparently former lath-shaped crystals. It is impossible to estimate the original constitution of the rock, but it may have had spilitic affinities.

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[1] *E.g., Baghanwala stage* for Salt Pseudomorph zone of Wynne; *Bassein series* for Nummulitic or Eocene series of Theobald; *Jhalmari stage* for *Cardita beaumonti* zone of Blanford; *Jutana stage* for Magnesian Sandstone of Wynne, etc., etc.

[2] *Rec. Geol. Surv. Ind.*, XXVIII, p. 62, (1895); *Pal. Ind.*, N. S., Vol. I, p. 5, (1899)

[3] *Rec. Geol. Surv. Ind.*, XXIX, p. 73, (1896).

To the north, in sheet 84 L/1, Mr. Clegg notes that the boundary of the Axials and Eocene becomes very indistinct near the northern margin (lat. 21°) of this sheet, and he thinks it probable that some Eocene rocks are folded in with the upper Axials. Direct evidence, however, was not forthcoming, and the rocks were too varied and crushed to permit of their stratigraphical relationships being determined.

In sheet 84 L/2, the Axials lie a short distance west of the Mon river, and occasionally the river actually crosses the boundary. Owing to the proximity of the Nwamataung range, the folding is more violent than in the more northerly area of 84 L/1.

Eocene basal conglomerate.

Dyke-rock.

From Buywa to Chiywa, in this sheet, on the banks of the Mon river, shales of Lower Eocene (Laungshe stage) age are exposed. Westwards, up the Chi chaung, is a band of metamorphosed conglomerate. A similar conglomerate is exposed on the Kanywa track west of Sidoktaya (in sheet 84 L/3, south of the country described in this memoir). The conglomerate on the Kanywa track is described by Mr. Clegg as consisting of quartzite pebbles from the size of sand grains to one inch diameter, in a mosaic of quartz with strain polarisation. The boundaries of the individual grains are sometimes ill defined. Mr. Clegg regards this conglomerate as the basal bed of the Nummulitics. Underlying this conglomerate, the Axials show fine grain contorted shales with some secondary silica; these are exposed about a quarter of a mile west of the conglomerates. At the same distance west of the new village of Chichaungywa are exposures of an igneous rock, consisting of an interlocking mass of andesine felspars of lath shape, the interstices being filled with calcite. The felspars do not vary in size, and the original rock must have cooled fairly slowly, probably in a dyke or small boss. From its texture, it seems to have been something between a trachyte and its plutonic equivalent. It certainly, however, could not be called a syenite porphyry. Boulders of jasper-like rock are very common in the river-bed of the Chi.

Agglomerate.

The village of Paiksok is situated about 6 miles N. N. W. of Chiywa, and is built on the western bank of the Mon on Axial strata. These strata must come close under the conglomerate mentioned above, which is exposed in the Chi. A green clay is here seen, soapy to the touch, and resembling the clays which are derived from the ashes of Mt. Popa. Near the exposure of clays there is seen in the river an isolated mass of agglomerate, about 20 feet high by 20 and 30 feet wide and long. The included trachyte bombs measured up to 8 inches in diameter and consisted of glomero-porphyritic felspars in a groundmass of the same mineral.

About three miles north of Paiksok, the Dwe chaung joins the Mon river. Near the junction with the Mon, it traverses Laungshe stage rocks, but over the greater part of its course it lies in Axials. Sandstone is found half a mile west of Dweywa, and is succeeded by contorted shales containing huge boulders of crystalline limestone. Half a mile west of a village two miles west of Dweywa, and named Ngakyiywa, was found a boulder of green decomposed trachyte, similar to that described above, but more decomposed.

About 11 miles N. N. W. of Dweywa is the village of Ngatawzok on the Mon. East of this village are conglomerates dipping north. These are probably the basal beds of the Nummulitics, and Axials lie to the west. Not quite seven miles north by west of Dweywa, the village of Longyi also lies close to the Axial-Nummulitic boundary. Half a mile south-west of Longyi is an occurrence of what appears to be a true pillow lava, the pillows lying in a loose decomposed matrix. The lava itself is a vesicular trachyte, and consists entirely of thin feathery laths of felspar, and microlites of the same mineral, while the vesicles are filled with calcite. The rock resembles that described above. It is underlain by shaly strata.

In this area, about 1 mile west of Taunggyin, on the boundary of the Pakokku Hill tracts, where it crosses the Mon river, there is an interesting exposure of a plutonic rock consisting of basic plagioclase, hornblende, and a little magnetite. With it are associated serpentine and agglomerates. To the west, a coarse conglomerate unconformably overlies serpentinous agglomerate. Similar conglomerates are seen about one and a third miles W. N. W. of Taunggyin on the Mon bank. Serpentine forms the steep western bank of the river, and in this serpentine, at a point two and a half miles west 30° north of Longyi, there is an occurrence of copper ore.

Globigerina Limestone.

West of Ngatawzok, down the Sin *chaung* in supposed Axial strata, are seen silicified trachytes, tuffs (about half a mile from the village), and a quarter of a mile further, a boulder of *Globigerina* limestone. Further west other crystalline limestones protrude through the shales. Here also a boulder of serpentinised peridotite was found.

Up the Mon river near Hmindingyin, a small village about two miles W. S. W. of Ngatawzok, the Axial rocks are the usual contorted and slightly metamorphosed shales and sandstones. These are followed by an agglomeratic type of rocks. On the boundary of the Pakokku Hill tracts, there is a rather gneissose quartz-diorite.

Two miles N. by W. of Ngatawzok is Sinchaung village. In several sections in this area crystalline limestone pushes through the shales. One mile south of the village are laminated vertical limestones and shales.

Four miles to the north, near Pyingyi, about one and a quarter miles W. N. W. of this village, is an exposure of *Globigerina* limestone. Further west other crystalline limestones protrude through the shales. One and three-quarter miles W. N. W. of Pyingyi are slightly metamorphosed and very contorted sandstones and shales.

In the north of sheet 84 L/1, south-west of the deserted village of Mehin, the Axials are composed of laminated shales and sandstones, with limy bands and calcite veins, all being very much contorted and faulted.

Immediately to the east of Mehin, a band of limestone with *Lithothamnion* is placed by Mr. Clegg in the Nummulitic group.

Schists, quartzites and shales.

In sheet 84 K/4, Mr. Clegg records that west of Yinye, the Paunggyi sandstones and conglomerates overlie Axial rocks consisting of contorted blue shales, and, to the west of these, contorted schists and slaty quartzites veined with calcite. Large boulders of schists are scattered over the valley floor; these are similar to some seen in the Kyauksit stream-bed in the south of sheet 84 K/3.

West of Thigon, a village about 4 miles south of Saw town in sheet 84 K/4, Mr. Clegg says that the Axials are a series of sandstones and shales, the latter slickensided, the former metamorphosed, and the whole very much contorted.

The above notes, taken from Mr. Clegg's progress reports, may be supplemented by observations by myself and others in the country to the north.

Mr. H. S. Bion collected some specimens of conglomerate from Swelegyin, in basal Nummulitic rocks overlying the Axials. These conglomerates contained small nummulites and *Orthophragminæ*, which point to an Eocene, obviously a lower Eocene, age.

Eocene basal conglomerates.

In the Saw river, at this horizon, I found similar conglomerates, and near Anyakadin, a village about three miles north by west of Saw, three furlongs to the north-west of the village, in basal Eocene rocks, consisting of coarse buff sandstone and shale, there were intercalations of limestone containing *Orthophragminæ* and small nummulites. The nummulites were about one millimetre in diameter.

Beneath these were axial rocks, consisting of sub-metamorphosed and highly contorted and disturbed shales, satin shales, horn-stones, fine-grained sandstones, sometimes with ashes, and some less altered sandstones.

Change of facies in Axials of Pakokku Hill tracts.

On the bridle-path from Saw to Kanpetlet, near Wunubaung, a gradual change of facies takes place in the Axials. The grade of metamorphism is higher to the west, and the rocks are mainly talc-schists, mica-schists, green chloritic schists, quartzites, vein quartz, steatite veins, and some satin shales and blue shaly schists. One of the commonest types is talc-schist containing iron oxide which weathers in bright red hues. These types are seen from Wunubaung to Kanpetlet, and westwards to the top of Mount Victoria, and the twin unnamed peak, 10,190 feet high, lying one mile to the west. The rocks closely resemble those seen around the steatite mines of the border of Minbu and Kyaukpyu districts, described by Sir H. H. Hayden[1].

"Kanpetlet schists."

When I first visited this area, I believed that these more highly metamorphosed rocks with predominant talc-schists should be separated as a different series from the Axials, and I named them provisionally the Kanpetlet schists. Subsequent mapping seemed to show that there was no sharp boundary between the more highly and the less highly metamorphosed groups. Rather there seems to be a gradual transition, by a gentle increase of metamorphism.

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[1] *Rec. Geol. Surv. Ind.*, XXIX, pp. 71-76, (1896).

Latterly I have been mapping the Hazara district in the North-West Frontier Province. One can there trace a somewhat similar gradual change in the Attock and Hazara slates, which in North Hazara become satin shales, phyllites, and schists. While I am of opinion that the Axials are probably a complex group, involving more than one series, I no longer adhere to the opinion formerly expressed that the lithological differences between the "Kanpetlet schists" and the Axial rocks to the west of them imply that they are different series.

In the section in the Kyauksit *chaung* in the south of sheet 84 K/3, west of Kyauksit village, there is a belt of coarse sandstones and conglomerates, which form low hills. They underlie the main portion of the Laungshe shales, but they themselves are underlain by shales of the ordinary blue softish type. The conglomerate, when traced northwards towards Hnaw in the north of the sheet, thins out, and the shales predominate. The conglomerate is therefore inconstant; nevertheless, from its stratigraphical position, it must be correlated with the Paunggyi conglomerate. The shales below are a downward extension of the Eocene or Nummulitic series, possibly into the upper Cretaceous. About two-and-a-half miles west of Kyauksit, Axial rocks occur of the types seen near Saw, that is mainly contorted sub-metamorphosed shales and sandstones.

Upper Cretaceous conglomerate.

In this area, I found a fossiliferous boulder of conglomerate lying loose in the stream-bed at the junction of the Kyauksit and Kyaw *chaungs*. The fossils were provisionally identified as *Nerinea* sp., and *Trochalia* sp., and pointed to an upper Cretaceous age.

We have seen however that the base of the Nummulitic series extends downwards into the Cretaceous in Henzada, where the coal-seams contained a turricone ammonite. Further it will be shown below that the basal beds of the Nummulitics in north Pakokku district between Tilin and Gangaw contain *Orbitoides apiculata*, *Cinulia* sp., *Roudaria* sp. and other fossils indicating the Danian stage. It is therefore probable that there are some outliers of the basal beds of the Nummulitic group involved in the folding of the upper Axials, and occurring as isolated patches west of the main outcrop of Tertiary deposits. This view is not inconsistent with the view that there is strong unconformity between these basal conglomerates and the Axials. The Kalaw Red beds of the Shan States are, in a somewhat similar manner, to some extent involved in the folding of the Loian series and Plateau Limestones beneath, while they themselves are of upper Cretaceous age and unconformable to the rocks below.

It is probable therefore that this piece of conglomerate with upper Cretaceous fossils comes from some Cretaceous outlier caught up in the Axials.

The *Cardita beaumonti* beds of the Hlwa stream in Thayetmyo, mentioned above, are similarly folded into the Axials.

A little over two miles to the west, the Axials change to the 'Kanpetlet schist' type, with predominant talc-schists.

Another spot where fossils were found in Axial country was on the hill path about two miles north-east of Wabotaung village in the south-west corner of sheet 84 K/3. Here coarse sandstone was found containing *Exogyra* sp. and *Orbitoides* sp. These coarse buff sandstones are however unlike the Axial rocks in appearance, and are probably an outlier of newer rocks resting unconformably upon the Axials.

Metamorphism of Axials.

The Axials were closely examined in the Che *chaung* section west of Yawmyo in sheet 84 K/3, but no fossils were seen in them. The rocks were sub-metamorphosed shales and sandstone. The change to more highly metamorphosed rock of the "Kanpetlet schist" type is seen between the third and fourth milestones on the bridle path from Minda Sakan to Yawmyo. The absence of any beds of coarse sandstone resembling the *Exogyra* beds found near Wabotaung is another indication that these beds are not part of the Axial group.

Around Kywechaung Yaphe village in the north-west corner of sheet 84 K/3, similar rocks are seen. The Axials are flaggy hard micaceous sandstones with traces of ash, and of a blue grey colour, interbedded with phyllitic or satin shales. The disturbance is intense. Westwards these beds pass into schists and phyllites through a more intense metamorphism, while the sandstone intercalations have dwindled. Vein quartz is common. In this region the transition from the less metamorphosed type to the more highly metamorphosed type is gradual, while southwards around Kanpetlet and west of Kyauksit, the transition is fairly sharp. There is no trace of fossils anywhere in the group.

In sheet 84 K/2, the Axials west of Kyi in the south of the sheet are exactly similar to those seen around Kywechaung Yaphe, and the transition from less to more metamorphosed rock is gradual. West of Tilin, the sections through the Axials are again similar to those already described.

Sheets 84 K/1 and 84 J/4 were mapped by Mr. B. B. Gupta. He describes the Axials in the west of K/1 as hardened sandstones and shales contorted and intersected by veinlets of calcite and quartz. The sandstones are sub-schistose; the shales approach the condition of slates. Rocks of Kanpetlet schist type were not seen. In sheet 84 J/4, some of the Axial beds were grey sandstones with enclosed fragments of black flattened shale. The Axials are a series of shales and sandstones, the shales almost slaty and with a silky lustre. Some of the shales are a pitchy or jet black hard rock, resembling the touchstones of some Indian goldsmiths. Mr. Gupta could not find any trace of fossils.

Age of Axials.

The account of the Axials given in the foregoing pages, if somewhat tedious, at any rate shows that they are in the main an unfossiliferous group of slaty shales and hardened sandstones, talc-schists, phyllites and mica-schists. Such occurrences as *Cardita beaumonti* in Thayetmyo, or of turricone ammonites in Henzada, or of *Nerinea*, *Trochalia*, *Exogyra*, *Orbitoides*, in the Pakokku district do not imply a Cretaceous age for the Axials. All these fossils are associated not with rock of Axial type, but with conglomerates and coarse sandstone. The *Cardita* beds are described as shale, but a reference to Theobald's original memoir will show that they are closely associated with conglomerate. Moreover rocks of the same Danian age as the *Cardita beaumonti* beds of Thayetmyo undoubtedly form the base of the Nummulitic group in the country north of Tilin in north Pakokku. The turricone ammonites come from beds definitely placed in the basal Nummulitics by Dr. Murray Stuart. The association of these fossils with conglomerates, coupled with other indications, is best explained by supposing that the Nummulitic group, with its Upper Cretaceous base, rests unconformably upon contorted and highly disturbed Axials of unknown age.

The only fossils, then, which are known to occur in the Axials, are the *Halobia* and *Monotis* from limestone in Thayetmyo in the same section in the Hlwa stream which yielded the *Cardita beaumonti* specimens, and again the *Globigerina* limestone of north Minbu described by Mr. Clegg.

This merely proves that there are Triassic limestones in the Axials, but these also may be outliers which have been isoclinally folded into the Axials.

Serpentine.

Again there are certain igneous intrusions of peridotite and serpentine in the Axials and the Negrais rocks as well as in the rocks of the Andaman Islands, and probably some interbedded lavas of contemporaneous age. It has been suggested by previous observers that the serpentine may be of Cretaceous age, but I see nothing to confirm this view. So far, no sign of serpentine intrusion into the Danian deposits along the eastern margin of the Arakan Yoma has been found. There is however a very curious sentence in Sir H. H. Hayden's report on the Steatite Mines of Minbu district[1], where he says:—

> 'At about half a mile west of Shauktaung the sandstones are underlain by thick beds of very finely laminated dark shale with occasional carbonaceous bands. In these shales occur at first narrow bands of sandstone, and beneath these a thick bed of grey limestone with nummulites in places; as a rule however in this neighbourhood, the limestones have been altered to such an extent by outbursts of a dark green serpentine that the fossils are unrecognisable.'

Sir H. H. Hayden does not say that the outcrop of Nummulitic limestone is itself altered by outbursts of serpentine, but there are evidently other limestones in the neighbourhood which have undergone considerable alteration. Sir H. H. Hayden was evidently inclined to correlate the altered Axial limestones with the Nummulitic limestone near Shauktaung.

A reference to Mr. E. L. G. Clegg's map of this area[2] shows that half a mile west of Shauktaung we are exactly on the boundary of the Lower Nummulitic and the Axials. The probability is that there are both Axial limestones here as elsewhere (see above), and also nummulitic limestone in the basal beds of the Nummulitics, as at Anyakadin near Saw (see *ante*), and that the former only are affected by serpentine intrusions.

It is quite impossible to suppose that the serpentine intrusions are as late as Eocene, as they nowhere affect Eocene rocks. If then the serpentine intrusions are really pre-Danian in age, the correlation with the serpentines of Baluchistan suggested by Mr. G. H. Tipper[1], falls to the ground.

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[1] *Op. cit.*, p. 74.

[2] Note on an Overlap in the Ngapo Area, Minbu District, *Rec. Geol. Surv. Ind.*, LXVI, pp. 250-264, and Pl. 10, (1933).

Age of the serpentine intrusions.

There are earlier basic intrusions in India than the Deccan trap and the serpentines of north-west India. The Rajmahal traps are not newer than Lower Cretaceous, and the Sylhet trap in Assam has been proved by Capt. R. W. Palmer[2] to be of pre-Ariyalur age. The mica-peridotites of the Bengal coalfields are more likely to be comparable in age with the peridotites and serpentines of the Yoma than the peridotites and serpentines of Baluchistan.

The question of the age of the Axials is closely linked with the similar uncertainty of the age of the Disangs of Assam.

Age of Disangs.

The age of the Disangs is discussed by Sir H. H. Hayden[3], whose description shows that these rocks closely resemble the Negrais and Axials of Burma, of which they may well be the northward continuation. He notes that in the Lushai hills Mr. T. H. D. La Touche found Cretaceous echinoids in beds similar to the Disangs. Also a fossil echinoid found at Lungleh in the Lushai hills and sent to the Geological Survey office for determination was referred by Mr. G. H. Tipper to the genus *Schizaster*.

With regard to the above evidence, it proves too much, for *Schizaster* is a Tertiary genus, abundant in the Oligocene, but the Axials are pre-Tertiary; therefore, these fossil occurrences may more probably point to the existence of outliers of Tertiary and Cretaceous age folded into the Axials.

Sir H. H. Hayden himself found a badly preserved ammonite, unfortunately unidentifiable, and some poorly preserved plant remains, also unidentifiable, in shales at the top of Nangkam hill near the Inspection Bungalow. Beds of carbonaceous shale also were found in the Disangs. Although carbonaceous shale has not been recorded from the Axials in Pakokku and north Minbu, such shales do occur in south Minbu, near Thetkegyin village on the road from Pa-aing to the steatite mines. The discovery of an ammonite proves the Mesozoic age of the rocks containing them, but, nevertheless, it would be rash to conclude that all that great and monotonous series of sub-metamorphosed slaty shales and fine-grain sandstones are therefore of Mesozoic age.

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[1] Geology of the Andaman Islands; *Mem. Geol. Surv. Ind.*, XXXV, p. 205, (1911).

[2] Geology of the Khasi and Jaintia Hills, *Rec. Geol. Surv. Ind.*, LV, pp. 143-168 and Pl. 27, (1923).

[3] *Op. cit.*, XL, pp. 285-288, (1910).

Sir E. H. Pascoe in his traverse across the Naga hills[1] describes similar rocks under the name of Disangs. Talcose phyllites like those around Kanpetlet were of common occurrence. He has described some interesting intrusions of gabbro, peridotite and serpentine. Associated with the Disangs was a conglomerate containing pebbles of serpentine which indicate that the conglomerate is of later age than the serpentine intrusions. West of the conglomerate lies a broad expanse of Disang beds; to the east Sir E. H. Pascoe found beds very similar to the Disangs, but differing in the greater degree of metamorphism to which they were subjected. These last he named the Makwari beds.

Age of Axials.

To sum up the evidences of the age of the Axials we have the following facts:—

i. The presence of conglomerates of age later than the serpentine intrusions: these conglomerates are later than the Axials but folded into them. They are unconformable to the Axials in north Minbu.

ii. An infold of Danian beds (*Cardita beaumonti* beds) in the Thayetmyo Axials, associated with conglomerates.

iii. Beds of Upper Cretaceous age resting upon Axials in Henzada and Pakokku.

iv. Serpentine and peridotite intrusions of pre-Danian age from the Andaman Islands north through the Yoma to the Naga hills and the Disangs of Assam.

v. Undoubted Triassic fossils in Thayetmyo, *Globigerina* Limestone of unknown age in north Minbu, plant remains and an unidentified ammonite in Assam.

vi. An immense extent of monotonous alternating successions of slaty shale and fine-grained sandstones, entirely unfossiliferous, except for the occurrences mentioned above.

It must be concluded that the Axials are probably a complex of rocks of varying age, but it is possible that the great bulk of them may be pre-Cambrian, or perhaps comparable in age to such groups as the Simla slates and the Jaunsar series. The few fossiliferous beds seen may represent infolds of rocks of later age, including Triassic strata.

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[1] *Op. cit.*, XLII, p. 257, (1912).

CHAPTER IV.

THE LOWER EOCENE AND UPPER CRETACEOUS BEDS.

Maw gravels.

The middle portion of sheet 84 K/1 is an area of great geological interest. The town of Tilin lies in the northern part of sheet 84 K/2 to the south of K/1. Tilin is built upon a gravel and sand formation first examined by myself, and named the Maw gravels. These gravels and sands yielded vertebrate remains which indicated a Lower Siwalik age. The vertebrate remains were thus an older fauna than those from the Irrawaddy sandstones, but, being late Miocene, they indicate that the deposits are newer than the main mass of the Pegu groups, which is largely Oligocene and Lower Miocene.

These Maw gravels form a syncline the axis of which runs due north from Tilin. They rest unconformably upon the Axials to the west, and to the east they are underlain by Cretaceous beds, but over a distance of about 12 miles along a portion of the eastern margin of the outcrop there is a thin strip of Yaw shales intervening between the Cretaceous beds and the Maw gravels.

The Yaw shales are indistinguishable lithologically in the field from the Cretaceous shales abutting on them to the east, and the geology proved puzzling at first.

Yaw shales of Maw valley.

A section through the north of sheet 84 K/1, by Mr. B. B. Gupta, is given on Plate 9, Sect. 9. The junction of the Cretaceous beds and the Maw gravels is faulted. The Cretaceous beds dip eastwards at angles of about 45°. To the south the dips are steeper, and often vertical. To the west of the strike-fault, a thin belt of Yaw shales (Upper Eocene) intervenes between the Maw gravels, and the strike-fault. These beds must be regarded as the normal succession below the Maw gravels. Just as the Irrawaddy sandstones around Myaing in sheet 84 K/14 are underlain by Yaw shales, without the intervention of Pegu strata, so also here t must be assumed that there is a stratigraphical gap representing the absence of most of the Pegu series between the Maw gravels and the Yaw shales. East of the strike-fault the Cretaceous shales abut on the Yaw shales, and, as the two formations are lithologically similar, the wide difference in age would not be suspected. The fossil evidence is however decisive. The Yaw shales contain *Gosavia humberti* (d'Arch. & Haime) and *Nummulites yawenses*, Cotter, both species typical of the Yaw stage, also *Operculina canalifera* and *Genotia* sp.

Orbitoides beds.

In the winter of 1914-15, I found *Orbitoides apiculata*, in the shales in the base of the Laungshe shale series. *Orbitoides apiculata* Schlumberger has been recorded by E. Vredenburg[1] from the *Hemipneustes* beds of Sind, which are regarded by him as of Maestrichtian age.

These *Orbitoides* beds were discovered in two localities, namely :—

(1) In the centre of sheet 84 K/2, about 1 mile 3 furlongs south of Aung, where the forest-path from Aung to Kyi crosses a stream. The fossiliferous bed is on the west of the road, about 50 yards downstream. Here were found *Orbitoides apiculata*, and broken molluscan shells.

(2) A quarter of a mile south of Kunze in the north of sheet 84 K/2, on the west bank of the road to Wayinchaing. Here also *Orbitoides apiculata* was found, and some poorly preserved, specifically unidentifiable mollusca, apparently of the genera *Pyrula*, *Dosinia*, *Natica*.

It has been mentioned above (page 33) that *Orbitoides* and *Exogyra* were found in coarse sandstone resting on Axial rocks on the hill-path near Wabotaung in the south-west corner of sheet 84 K/3.

In the winter of 1921-22, Mr. B. B. Gupta continued the geological mapping of the area north of Tilin. *Orbitoides apiculata* was found in the following localities :—

(3) About three furlongs S. S. W. of triangular point 1988 in the south of sheet 84 K/1, that is about two miles east of mile 104 furlong 4 on the Pakkokku-Gangaw road.

(4) About 7 furlongs W. N. W. of Kyanyin, that is about two and three-quarter miles east of mile 110 furlong 4 on the Pakokku-Gangaw road.

(5) Footpath about one and a half miles south of Yeshin, that is about two and a quarter miles east of Aingma near mile 111 on the Pakokku-Gangaw road.

Ranikot beds of Yeshin.

This last locality, which may be called the Yeshin locality, is very important. Here two fossil beds were found, one with *Orbitoides* of Upper Cretaceous age, and a higher bed with a Ranikot fauna. The rocks are shales with some subordinate sandstone bands. The two fossil beds are separated by 180 feet of strata. In the lower bed the following species were found :—

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[1] *Op. cit.*, XXXVI, p. 204, (1908).

Orbitoides apiculata, Schlumb.
Orbitolina sp.
Cyprimeria sp. cf. *C. analoga*, Forbes
Cinulia sp.
Roudairia sp.

In the higher bed the following :—

Strepsidura indica, C. & P.
Calyptrophorus indica, C. & P.
Calyptrophorus hollandi, C. & P.
Lyria cossmanni, Vred.
Athleta eugeniae, Vred.
Athleta burtoni, Vred.
Athleta nœtlingi, C. & P.
Drillia jhirakensis, C. & P.
Murex lyelli, D'Arch.
Volutilithes sp. cf. *cithara*, Lmk.
Faunus vulcanicus (Schl.)
Pyrazus pyramidatus (Desh.).

The above list is taken from the General Report for 1923 of the Geological Survey of India[1]. Of the species listed, the first eight are Upper Ranikot species, but it is not possible to be precise about the exact horizon. *Murex lyelli* is perhaps an uncertain identification. L. R. Cox (communication by letter) thinks that D'Archiac's original type is a Gaj species, and an immature specimen. Vredenburg[2] says that its horizon in Sind is unknown.

The last three identifications recall foreign species, but are not known from India. It is interesting, however, to note that *Pyrazus octogonus*, Cox[3] from the Lower Ranikot of the Hangu shale is a close relative of *P. pyramidalis.*

There is enough evidence, however, to render quite certain the correlation of this horizon with the Ranikot stage of Sind. The lower fossil bed with *Orbitoides apiculata* is also equally certainly an Upper Cretaceous horizon, and very probably comparable with the *Cardita beaumonti* beds of Sind.

[1] *Op. cit.*, LVI, p. 43, (1924).
[2] *Mem. Geol. Surv. Ind.*, L, Pt. 1, p. 216, (1925).
[3] *Pal. Ind.*, N. S., Vol. XV, p. 150, (1930).

The section at Yeshin also shows the close connection of this Cretaceous horizon with the Lower Eocene, which may perhaps recall the similarly close connection of the *Cardita beaumonti* beds of Sind with the Ranikot stage above. It affords evidence that this Cretaceous horizon lies not in the Axials, but in the succession of shales and subordinate sandstones immediately above them, the bulk of which are Eocene.

In the Yeshin stream, about 6 or 7 furlongs south-west of Yeshin, the beds are steeply dipping to vertical, and the strike-fault is crossed. Yaw shales occur on the other side (west) of the fault, and in them, in the stream section, the Yaw stage fossils abovementioned, *Nummulites yawensis*, *Gosavia humberti*, *Operculina canalifera*, and *Genotia* sp. were found.

Another locality where fossils were found in the lower part of the Laungshe shales is on the cart-track, about three-quarters of a mile south-west of Letpan, a village on the southern margin of sheet 84 K/1. Here were specimens of an *Orthophragmina* resembling *O. trigonalis*, Ch. Risp. This indicates an Eocene age, and shows that the Cretaceous base of this suite of rocks is very limited in thickness.

Some three and three-quarter miles to the E. N. E. of the abovementioned village of Letpan, on the path from Kabaungdaw to Sinzwe, the Laungshe shales contained the well known Laki zone fossil *Nummulites atacicus*, Leym.

Laki age of Upper Laungshes.

It is clear therefore, that the lower division of the Nummulitic group of Burma contains three distinct faunas, *viz.* :—

3. Laki or Ypresian.
2. Ranikot or Thanetian to Montian
1. Upper Cretaceous, Danian probably.

All along the foothills of the Arakan Yoma on its eastern flank, wherever the Lower Eocene has been examined, it appears to be mainly a deposit of shale with subordinate sandstone bands, and with conglomerate beds at or near the base in most sections. The conglomerates are however inconstant, and die out or attenuate in certain areas; in sheet 84 K/3, there is a distinct belt of shales below the conglomerates, between them and the Axials.

These beds were named by me in 1915 the Laungshe shales.[1] This name was adopted at the suggestion of Mr. H. S. Bion, who

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[1] *Rec. Geol. Surv. Ind.*, XLV, p. 270, (1915).

Swelegyin or Paunggyi conglomerate.

examined a good section through these shales in the south of sheet 84 K/4, in an area where Laungshe is the principal village. To the west, in this area, conglomerates were developed around the village of Swelegyin. I examined under the microscope some sections from the conglomerate at Swelegyin, given to me by Mr. H. S. Bion, and found them to contain *Orthophragminæ* and small nummulites; the conglomerate is therefore Eocene, and newer than the Cretaceous beds of Yeshin described above. To the north near Anyakadin, a village close to Saw, there is coarse buff sandstone, but true conglomerate was not seen. A limestone in the stream 3 furlongs north-west of Anyakadin contained *Orthophragminæ* and small nummulites, and, as the Axial boundary lies very close here, the Cretaceous beds must be absent from the base of the group.

The conglomerates of Swelegyin, were shown, as mapping proceeded, to be developments within the Laungshe shale group. In sheet 84 K/3, the conglomerate band dies out in the country north of Te, and the lower Laungshes consist of shales with subordinate sandstones. In the country to the north, there is no well marked belt of conglomerate near the Laungshe base. Both at Anyakadin near Saw in sheet 84 K/4, and at Swelegyin in the south the conglomerate is demonstrably Eocene, since it contains small *Orthophragminæ*.

Unconformity at base of Eocene suite.

In sheet 84 L/1, Mr. Clegg found that the beds at the base of the Eocene group were greatly disturbed. Owing to this, the succession was not clear. In the south of this sheet, about three miles south-west of Longyi, a coarse conglomerate unconformably overlies the serpentinous agglomerates of the Axial group. This section appears to show that the Eocene group rests unconformably upon the Axials.

Between Longyi and Pani, to the north-west, the Laungshes contain soft fawn sandstones with hard gritty bands; these beds form a distinct hill-range.

In the north of sheet L/1, near Kyawgyaung, there are conglomerates, which are well developed one mile north-west of the village. There are also hard sandstones on the site of Mohin deserted village, with, to the eastward, shales containing *Lithothamnion* limestone. Although there is no mappable continuous belt of conglomerates in this area, the development of conglomerates in the basal Laungshes is quite usual. In sheet 84 L/2, west of Nabedon, in the north of the sheet there are grits, with vertical dips, on the Axial-Eocene boundary. They are unmetamorphosed, and Mr. Clegg places them in the Eocene. Near Dweywa, there is an exposure of sandstones, which are succeeded by contorted shales containing huge boulders of crystalline limestone and other Axial rocks. Further south, conglomerates are again exposed in the Chi *chaung* near Chiywa, and again west of Sidoktaya.

Lower Laungshes.

It is clear from the foregoing account that these conglomerates do not form a continuous mappable belt, but are rather developments within the Laungshe Shale, which tend to become conglomeratic near their base. Similar conglomerates were first described by me near Paunggyi village, about three miles S. by E. of Ngape town in the south-west of the Minbu district[1], and the name "Paunggyi conglomerate" was applied to this horizon in subsequent papers.[2]

It must be recognised, however, that these conglomerates are too inconstant to be separated off from the Laungshes as a distinct formation.

Middle and Upper Laungshes.

Above the conglomerate belt, the Laungshes consist mainly of blue shale, very sparsely fossiliferous. In sheets 84 J/8 and K/5, Mr. F. W. Walker reports that the boundary between the Tilin sandstones and the Laungshe shale below is sharp. The Laungshes, he says, are composed almost entirely of blue shale, (he speaks of the exposures of upper Laungshes in the above-named sheets, and does not deal with the basal beds). These shales are generally thinly laminated, but often concretionary. Bands of blue clay are common. Thin layers of sandstone occur throughout the series, but in the upper horizons these amount to several hundred feet in thickness. Tracing them laterally, it was found that they were inconstant and passed into shales. One of these sandstone beds is well exposed in a stream-bed two miles north-east of Myekmyaung in the north-west quadrant of sheet 84 K/5. This bed contained small bands of conglomerate in a ferruginous matrix. In the stream that runs past Chaing in the north-west corner of the same sheet, purple beds resembling the vertebrate-bearing beds of the Pondaung sandstones were seen in the Laungshes.

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[1] *Op. cit.*, XLI, p. 229, (1912).

[2] See *Op. cit.*, XLV, p. 270, (1915), and *Journ. Asiat. Soc. Bengal*, New Ser., IV, p. 415, (1918).

Mr. Walker proceeds to say that thin layers of selenite are abundant throughout the Laungshes, and traces of fragmentary and unidentifiable fossil plants were found. Owing to the soft nature of the beds, local contortion is very common. There may be some slight reduplication of the beds, due to this, but no general fold structure was found, such as might cause extensive reduplication.

Mr. B. B. Gupta, who mapped sheets 84 J/4 and K/1, gives a somewhat similar account of the Laungshes. The basal beds described by him have already been dealt with above. He notes the presence of selenite in both sheets, the frequency of minor faults and local crumpling. There are lenticular bands of limestone in the Laungshes near Kyaukku in sheet 84 J/4. There is a synclinal fold in the Laungshes in the south of J/4, about long. 94° 12′.

Laki fossils in Laungshes.

Mr. Gupta found *Nummulites atacicus* in the Laungshes in the following localities:—

(1) 5 miles north-east of Myaukkon. Myaukkon is a village little over a mile north of Gangaw town in sheet 84 J/4.

(2) 7 miles E. N. E. of Minywa, which village is at the 128th milestone on the Pakokku-Gangaw road, in the south of sheet 84 J/4.

(3) 1 mile, 3 furlongs north-west of Kabaungdaw, a village in the south-east corner of sheet 84 K/1. With the nummulites from this locality were found some mollusca provisionally identified as *Protocardium* sp., and *Mytilus* sp.

In the north of sheet 84 K/4, near the top of the Laungshes, Mr. Clegg reports the occurrence of *Nummulites atacicus* and *Operculina canalifera* from a section in the Kyein *chaung*.

The occurrence of *Nummulites atacicus* in rocks of similar age has been records by Mr. G. H. Tipper in his memoir on the Andaman Islands[1], and I have elsewhere[2] noted that both Mr. P. N. Datta and Mr. Sethu Rama Rau found specimens of this fossil in the lower Eocene of the Thayetmyo district.

Thickness.

The thickness of the Laungshe shales including the conglomeratic zone near the base is impossible to estimate accurately owing to the frequent faulting and minor folding. In a previous paper[3], I estimated the thickness as follows:—

(1) Paunggyi conglomerate zone . . .	2,000 to 4,000 ft.
(2) Laungshe shales, above conglomerate . .	9,000 to 12,000 ft.

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[1] *Mem. Geol. Surv. Ind.*, XXXV, Pt. 4, p. 6, (1911).

[2] *Rec. Geol. Surv. Ind.*, XLI, p. 322, (1912).

[3] *Journ. Asiat. Soc. Bengal*, New Ser., XIV, p. 415, (1918).

CHAPTER V.

THE TILIN SANDSTONES.

Variation in thickness.

The Tilin sandstones were first examined and described by me in field-season 1913-14. They were first observed between milestones 75 and 81 on the Pakokku-Tilin road, and form a fairly constant sandstone belt in this area, underlying the Tabyin clays, and overlying the Laungshe shales. They vary in thickness, however, thinning out considerably to the north, and thickening somewhat in the area immediately south of the road-section. They are still a fairly well marked belt as far south as Saw and east of Longyi, but they taper out again as we approach Sidoktaya, and in the country south of Sidoktaya, which lies outside the area dealt with in this memoir, they become inconstant, and are absent in some sections.

Fauna.

The Tilin sandstones are sparsely fossiliferous. On the road from Pauk to Yawmyo, between the 31st and 32nd mile, I found two fossil beds from which Mr. S. Sethu Rama Rau collected some small nummulites, an *Ampullina*, and a *Volutilithes*. These were not identified with any known Indian species.

In the south of sheet 84 K/3, between Hnetchaung and Kachaung, only thin beds of sandstone intercalated with shale were seen on the strike of the Tilin sandstone. But there were not many exposures along the section, owing to heavy forest and some stretches of alluvium. It may also be noted that the Tilins are not entirely sandstone, but predominantly a sandstone formation, and that exposures on high ground give a false impression of the proportion of sandstone to shale, by reason of the concealment, as a rule, of thin shale beds in debris and earth, while the harder sandstones outcrop frequently. In the Saw river section, massive Tilin sandstones are seen west of Pole, (a village about three miles east of Saw).

Lateral variation.

Making allowances for the obscurity of sections through these sandstones, owing to forest and lack of clear exposures, the impression still remains that these sandstones vary considerably laterally, being alternations of sandstone and shale in the area between Hnetchaung and Kachaung, but fairly massive elsewhere.

In the road-section mentioned above, between the 75th and 81st milestone, (Pakokku-Tilin road), the horizon is well marked and the sandstones are at least 5,000 feet thick. In this area the upper zones of the sandstones have a very freshwater appearance, and contain abundant silicified wood. Red earth and gravel beds occur also. West of Yedu, a village near mile 71 on the above mentioned road, the sandstones contain grains of felspar and some chalcedony, and are possibly ashy. Their general colour is greenish buff, and the sandstones vary from coarse to fine grain.

Lithology.

In sheet 84 K/5, which area was mapped by Capt. F. W. Walker, the average thickness was estimated as 3,300 feet. The upper boundary between the Tilins and the Tabyin clays was sharply defined. The sandstones of this area are fine-grained and compact, in fairly thick layers and with numerous joint-planes. They have a greenish tinge, in this respect resembling the Pondaung sandstones, and they have subordinate bands of shale interbedded. These shale intercalations are more frequent in the south of the sheet near Sobya. The formation forms a minor swelling on the western side of the Ponyadaung range, and the thickness is fairly constant, except in the south near Sobya, where the sandstones thicken.

Fossils.

Capt. Walker found a fairly constant fossil band in sheet 84 K/5, but the band was not found in the sheet to the north (84 J/8). The following is a list of the fossils collected by Capt. Walker, and the identifications are his :—

List of Fossils collected by F. W. Walker from the Tilin sandstones, (season 1922-23).

Reg. No. in G. S. I. collections.	Locality.	Identifications.
K22/332	(1) Tante *chaung* 5 furs. east of Sobya.	(1) *Crassatella* sp., *Ostraea* sp., *Ceritheum* sp., *Arca* sp., *Tellina* sp.
K22/333	(2) Tante *chaung* 200 yds. east of above.	(2) *Ceritheum*, *Arca*, *Natica*, *Athleta*, *Mitra*, Bryozoans.
K22 334	(3) Tante *chaung* 150 yds. south-east of above.	(3) *Turritella*, *Ceritheum*, *Natica*.

List of Fossils collected by F. W. Walker from the Tilin Sandstones, (season 1922-23)—contd.

Reg. No. in G. S. I. collections.	Locality.	Identifications.
K22/335	(4) Tin *chaung*, 3 furs. west of 30 feet waterfall.	(4) *Pectunculus*, *Serraticeritheum* cf. *blainvillei* Desh., *Crassatella*.
K22/336	(5) Tin *chaung*, 150 yds. south-west of above.	(5) *Ampullina*, *Arca*, *Turritella*, ? *Nerita*.
K22/337	(6) Tin *chaung*, 50 yds. west of above.	(6) *Arca*, *Volutospina*, *Corbula* cf. *ficus* Brander, *Ceritheum*, *Meretrix*, *Pectunculus*, *Conus*.
K22/338	(7) Tin *chaung* 300 yds. west of above.	(7) *Turritella*, *Ceritheum*.
K22/339	(8) Hnyinsauk *chaung*, 1 ml. 7 furs. east of Shawbyubin.	(8) *Crassatella*, *Natica*, *Ostraea*, *Turritella*, *Arca*, *Oliva*, *Ceritheum* cf. *labiatum* Desh.
K22/340	(9) She *chaung*, 100 yds. north of point 1643.	(9) *Natica*, *Arca*, *Mitra*.
K22/342	(10) Myekmyaung *chaung*, 3 mls. E. 15°N. of Myekmyaung.	(10) *Ceritheum*, *Natica*.
K22/341	(11) Yebok *chaung*, 3 furs. east of Forest Reserve.	(11) *Ceritheum*, *Turritella*, *Pleurotomaria*.
K22/343	(12) Chaing *chaung*, 1¼ mls. E.N.E. of Chaing.	(12) *Turritella*, *Ceritheum*, *Mitra*.

In the absence of specific identifications, it is impossible to discuss the age of this fauna which, however, is obviously of Eocene affinities.

In sheet 84 K/5, Mr. B. B. Gupta found an *Ostræa* in the Tilin sandstones about ¾ mile east of Sobya. This species was closely allied to *O. bellovacina*.

In a locality 1¼ miles E. S. E. of Shawbyubin, Mr. Gupta found the following:—*Anomia striata*, *Velates* sp., *Ancilla* sp., The Tilin sandstones of this area were of similar appearance to those described above. In sheet 84 J/4, Mr. Gupta found some hot springs in the Tilin sandstones north-east and south-east of Kunze.

The country south of Saw was mapped by Mr. E. L. G. Clegg. He found that the Tilin sandstones contained a middle shaly belt, with massive sandstone above and below. East of Thigon (a village some two miles south of Saw), Mr. Clegg describes the Tilins as consisting of two main bands of sandstones, themselves being alternate massive bluish and laminated fawn-coloured bands, separated by a thick belt of shales. The lower sandstone band contained a fossil bed crowded with *Ampullina*.

About 3 furlongs N. W. by N. from Kyaukmyaung rest-house, which lies some four miles south-east of Saw, Mr. Clegg found in the Tilins the following fossils:—

Arca (*Nœtia*) *pondaungensis*, Cotter.
Corbula semitorta, Bottger.
Axinea cf. *puruensis*, Martin.
Melania sp.
Athleta sp.
Cardita sp.
Mactra sp.

In sheet 84 L/1, the Tilins show the same tripartite division into upper sandstones, middle shaly belt, and lower sandstones. The middle shaly belt is well exposed under Thangyin village on the south margin of sheet 84 K/4, and south-east of Magyizu in the north of 84 L/1. The upper sandstone band grades into coarse sandstones with conglomerates.

Tilins of north Minbu.

About the centre of 84 L/1, there is a village named Kyauk-a. South of this village a long ridge of sandstone with pronounced westerly scarp runs in a S. S. E. direction to Kwemalaung village, (about the middle of the eastern margin of 84 L/2). Here the Ti stream breaks through, but the ridge still continues in a southerly direction on the western margin of 84 L/6 to a point about six miles north of Sidoktaya. This ridge in the neighbourhood of Kyauk-kok consists of a lower massive sandstone belt overlain by alternating sandstones and shales.

In a traverse from Peinchaung to Onwa in the south of 84 L/1, the sandstone scarp of the Tilins rises to a height of 3,100 feet. West of Onwa, conglomerates were seen and there was much contortion. West of the Tilins, the Laungshe shales are much squeezed and broken.

In sheet 84 L/1, Mr. Clegg has shown the Tilins to be reduplicated in echelon fashion by two strike faults running S. S. E. To the south of this reduplicated belt, they thin out regularly, becoming an inconspicuous band in the south-eastern corner of 84 L/2 near Sidoktaya. In the country west of Tilin, the thickness of the formation is very variable, from 2,000 to 5,000 feet.

CHAPTER VI.

THE TABYIN CLAYS.

The name 'Tabyin clay' was first given by me to the clays underlying the Pondaung sandstone in south Pakokku. The name is taken from the village of Tabyin, a village about 13 miles due west of Pauk, which lies on these clays.[1]

Lithology.

As exposed near Tabyin, these clays are rather darker in colour than the Yaw shales (*see* below), being a dark indigo blue, clunchy, full of carbonaceous markings and of tiny brown specks of lignite. They often show concentric weathering. Interstratified with them are layers of grey fine-grained sandstone, with occasional patches of pebbles, and usually in thin flat layers. The exposures show much disturbance, due to the overriding of the massive Pondaung sandstones above them. Neither the upper nor the lower boundaries are very clearly defined; the upper boundary certainly shows a gradual passage into the Pondaung sandstones.

Fossils.

Very few fossils were found in these clays. On the south bank of the Yaw river, near Myaukma Kyin, a village 7 miles S. S. E. of Tabyin, Mr. G. H. Tipper found a nummulite, which I identified a *N. vredenburgi*, Prever. W. L. F. Nuttall regards this species as identical with *N. acutus*, Sow.[2] It is found in India in the middle Khirthar. This species gives us a valuable hint of the correlation of the Tabyin clays with the Eocene rocks of north-west India.

Opposite Nyaungkan, on the Yaw river, 9 miles N. N. E. of Saw, I found some friable specimens of *Arca* (*Nōetia*) *pondaungensis*, Cotter, a species of common occurrence in the beds above.

Microscope sections of the sandstone intercalations in the Tabyin clay near Myaukma Kyin showed that they contain ash.

Upper boundary.

Capt. F. W. Walker, in his report on sheet 84 K/5, says that the passage from the Pondaung sandstone to the Tabyin clay is gradual. Tracing the Pondaungs downwards, he observed first a belt of shales and clay containing traces of coal; then a prominant band of hard sandstones, and below these the characteristic rocks of the Tabyins. These, he describes as greyish blue shales and clays, which predominate and somewhat resemble the Yaw shales. A thin laminated variety is common, but in other sections the clay is rubbly. Thin bands of hard compact sandstone, which occur regularly throughout the formation, help to distinguish it from the Yaws. In some outcrops sandstones are as prevalent as shales, but generally they are subordinate. Outcrops of blue clay which weathers into a soft mud are frequently seen; also a few thin layers of septarial matter. Thin seams of coal characterise the Tabyins of this area, up to a maximum of 18 inches thick. The formation weathers quickly, owing to the soft character of the beds, and, where it has been subjected to pressure, shows much contortion and irregularity. Except for a few poorly preserved lamellibranchs, not specifically identifiable, the formation is barren of fossils.

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[1] See *Rec. Geol. Surv. Ind.*, XLIV, p. 164, (1914); XLV, p. 270, (1915); *Journ. Asiat. Soc. Bengal*, New Ser., XIV, p. 415, (1918).

[2] *Rec. Geol. Surv. Ind.*, LIX., pp. 126, 133, (1926).

Changes in facies.

Mr. B. B. Gupta notes that, in sheet 84 K/5, the Tabyins are more arenaceous than in the country to the south. Capt. Walker estimates the thickness of the Tabyins as 4,000 feet. In the country to the south, I suggested a thickness of 5,000 feet. Mr. E. L. G. Clegg, who mapped sheets 84 L/1, L/2, and the western margins of 84 L/6, and L/7, and parts of 84 K/4, notes that the Tabyins are typically blue shales, reinforced by occasional thin bands of sandstone and thin lenticles of limestone. The blue shales are very fine-grained, and show much contortion. No fossils were found. Owing to the contortion, the thickness could not be estimated. Mr. Clegg notes that the Pondaung-Tabyin boundary cannot be mapped with any great precision.

In the country mapped by myself and Capt. F. W. Walker, there are several oil-seepages and gas-pools in the Tabyins. These will be dealt with in the economic chapter, (*see* page 127).

Generally, the formation is a clay one with sandstone reinforcements, showing a more arenaceous character as it is traced northwards; the thickness is variable, around 4,000 feet. Its age is probably middle Khirthar, since *N. acutus* characterises the lower part of the middle Khirthar. In European terminology, the age is Lutetian.

CHAPTER VII.

THE PONDAUNG SANDSTONES.

Introduction.

The formations hitherto described have been sparsely fossiliferous, and, with the exception of the very interesting faunæ of *Cardita beaumonti* and of Ranikot age, there have been few guides to indicate the exact age. Nevertheless, *Nummulites atacicus* and *N. acutus* have been found in horizons where we might have expected them to occur. But on the whole the rocks below the Pondaungs lack the interest which a rich fauna gives. Although it must not be supposed that the Pondaungs themselves are rich in fossils, yet they have yielded a mammalian fauna of great importance to palaeontology. These mammalian fossils were the first of their kind to be collected from Asiatic deposits, but they have now been overshadowed by the richer and more extensive fauna of Mongolia. Burma has, however, the distinction of having first given to science these fossil mammals from Asia.

The name 'Pondaung sandstones' was first adopted by me[1] to designate the formation, mainly sandstone, lying between the Yaw shales above, and the Ṭabyin clay below. Previous observers of the Yaw river section had imagined, from the lithological resemblance to the lower Pegus of north Minbu, that these rocks were to be correlated with the basal beds of the Pegu series. I proved, however, in the paper above-quoted and in subsequent papers, that the age of the Yaw shale above was Upper Eocene and that, in consequence, the Pondaung sandstones must also fall in the Eocene. This view has since been confirmed by Dr. Pilgrim and others who have examined the mammalian fauna.

The doubts which at first were entertained regarding the exact correlation of these beds with those of the Minbu district were due to the fact that the intervening country had not been mapped, and that the fauna of the Pondaungs was unknown, and that of the

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[1] See *Rec. Geol. Surv. Ind.*, XLIV, p. 164, (1914).

Yaw shale very imperfectly studied. But shortly after my study of the Yaw river section, my colleague, Mr. H. S. Bion, mapped the country between north Minbu and the Yaw river, and confirmed my opinion that the Yaw shales were to be correlated with the *Velates* beds of Minbu, and that the Pondaung sandstone corresponded with the main sandstones of the Nwamataung.

Distribution.

It will be seen from an examination of the map, that, while the formations hitherto described, (Laungshes, Tilins, Tabyins) occur only in the foothills of the Yoma and Chin Hills, the Pondaung sandstone and Yaw shales, besides their outcrops in the western tract, cover a wide area in the uplands north-west of Myaing. It is this latter tract which has produced the bulk of the vertebrate fauna of the Pondaungs; the Pondaungs of the Pondaung range west of Pauk appear to be barren of vertebrate fossils, but contain a few lamellibranchs.

Two facies.

The facies of the formation in the Pondaung range is thus rather different from that of the upland tract north-west of Myaing, and it will be best to treat the two areas separately.

The Pondaung sandstones form the main formation which builds the Nwamataung range in north Minbu, the Yeyodaung and Dudawtaung on the borders of Minbu and Pakokku, and the Pondaung and Ponnyadaung ranges of Pakokku and Lower Chindwin.

In these hills, the Pondaungs are generally coarse, often current-bedded, sandstones, with fossil wood and occasional bands of shale, which become more and more frequent towards the base of the stage, thus forming a passage into the Tabyin clay below. They contain strings and thin seams of coal, which are of no economic value. There are several outcrops of oil-sand and seepages of oil and of gas, which will be more fully described in the chapter on economic geology, (*see* page 129).

In the country around and to the immediate north of the Yaw river, the Pondaungs vary very much in thickness. In the section through Kyauktaga village westward in the north of sheet 84 K/6, they are about 5,500 feet thick; along the road from Pauk to Pasok, they are reduced to 3,500 feet, while in sheet 84 K/6, they swell out to nearly 8,000 feet.

In this tract, a few fossil beds were found, but only the following species have been identified[1] :—

Fossils of marine facies.

- *Arca* (*Nöetia*) *pondaungensis*, Cotter, from the top of the Pondaung range west of Kyauktaga. This species occurs also north of Chaungbyu village in Minbu district at a similar horizon.[2]
- *Corbula daltoni*, Cotter, from a fossil bed ½ mile south-east of Anein village in sheet 84 K/3. Also recorded under the name *C. harpa*, D'Arch. and Haime, by L. V. Dalton from south Minbu.[3]
- *Alectryonia newtoni*, Dalton, in Pakokku from the same bed near Anein as the preceding species. Also recorded by L. V. Dalton from rocks of similar age in south Minbu.

Scanty as the fauna is, there is some evidence for a correlation with the beds below the *Velates* horizon in south Minbu, and the relationships of the species are Eocene.

Boundaries.

Although the lower boundary of the Pondaungs is vague and the passage to the Tabyins gradual, the upper boundary between the Yaw shale and the Pondaungs is sharply defined in the country west of Pauk.

In the country to the north (sheet 84 K/5), which was mapped by Capt. F. W. Walker, there is the same quick passage from the Yaws to the Pondaungs. Capt. Walker states that the formation is about 7,000 feet thick. In the valley of the Kyaw river, there are seams of coal in the Yaws near the junction with the Pondaungs. In the Khodaung syncline in the south of 84 J/8, the boundary is marked by laterite six inches thick. This he thinks to be an old land surface.

Freshwater facies.

The formation, he says, is almost entirely composed of massive quartz sandstones, brown on the weathered surface, but of a greenish tint in fresh stream sections. Near the top of the series a fairly thick belt of reddish purple clays occur, while another similar belt, but neither so thick nor so regular, was observed further down. These beds are of special interest, since they contain vertebrate remains. It is to be noted that these beds do not occur in the country west of Pauk, where the facies is of a shallow water but marine type. In the

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[1] The Lamellibranchiata of the Eocene of Burma, *Pal. Ind.*, N. S., Vol. VII, Mem. No. 2, p. 20, (1923).

[2] The Pegu-Eocene Succession in the Minbu district near Ngape, *Rec. Geol. Surv. Ind.*, XLI, p. 227, (1912).

[3] L. V. Dalton, 'Geology of Burma'; *Quart. Journ. Geol. Soc.*, LXIV, p. 637, (1908).

Khodaung tract, where the dip is low, a large area of the bed becomes exposed. As the softer material is washed away, the hard fossils remain upon the surface. The only identifiable vertebrates from this tract were collected near Kyawdaw village in 84 J/8.

In this tract, thin conglomerate bands occur, in which quartz pebbles abound, but there are also pebbles of sandstone, serpentine and mudstone. Near the base, one of these bands seems fairly constant. The strata are regularly bedded with little current-bedding. Capt. Walker also found a few badly preserved shells in sheet 84 K/5 near the junction of the Kyin and Ktaw streams. Fossil wood, he observes, is found throughout the Pondaungs, but tends to be carbonised in the lower, and silicified in the upper horizons.

No change of facies was seen in the main range of the Pondaung and Ponyadaung, and the purple clays with vertebrates seemed to be confined mainly to the Khodaung synclinal area.

Some gas seepages were observed.

Marine facies of Pondaungs in north Minbu.

In the country north of Sidoktaya, Mr. E. L. G. Clegg describes the Pondaungs as a series of false-bedded fawn to blueish sandstones, about 1,500 to 2,000 feet thick. These sandstones, he says, are devoid of any distinct fauna, but contain silicified fossil wood towards the base. To the south they become less massive, and here there are some fragmentary fossil bands in which occur a large *Ampullina* which ranges up into the Yaw stage above, and an *Ostræa.*

From the latitude of Saw southwards, the Pondaungs thin out rapidly, so that the thickness given by Mr. Clegg as a maximum for the country around Sidoktaya (1,500—2,000 ft.) is very much less than the thickness west of Pauk and east of Tilin.

Freshwater facies.

Turning now to the uplands north-west of Myaing, we encounter a facies of the Pondaungs very different from that of the ranges to the west. North of Myaing, the upper Pondaungs are sandstones interstratified with very abundant beds of highly coloured earths. In many exposures one observes successive beds of cherry-red, bright buff, and cream-white earths interstratified with brown or buff sandstones. The basal beds are very coarse conglomerates and boulder beds, with boulders of altered dolerite, gneiss, and schist.

Mr. B. B. Gupta observed similar rocks in the formation in sheet 84 K/9. He found an ironstone bed near the top of the Pondaungs near Konywa, and several bands of selenite. There were earthy beds in cherry-red, chocolate, brown, cream, and ashy grey colour; these were highly arenaceous, with much ferruginous matter. The conglomerates of the lower Pondaungs contained pebbles and boulders of granite, diorite, quartz-augite rock, rhyolite, trachyte, porphyry, porphyrite, quartzite, jaspideous rock, etc.

Mammalian fauna of Pondaungs.

As has been observed above, the earthy beds contain vertebrate remains. The first discovery of these fossils was made by myself in 1914,[1] and the fauna was described by Dr. G. E. Pilgrim and myself in 1916 in a subsequent paper and, after further collections had been made in subsequent years by Mr. B. B. Gupta and Mr. H. M. Lahiri, two further monographs, which were published in 1925 and 1928, appeared in the *Paleontologia Indica* from the pen of Dr. Pilgrim upon the same subject.[2]

In my original collection, 95 per cent. of the specimens collected belonged to the *Anthracotheriidæ*, and similar proportions were to be observed in the subsequent collections of Mr. B. B. Gupta and Mr. H. M. Lahiri. In this respect the fauna resembles that of the Bugti hills in Baluchistan, which shows a similar preponderance of the same family.

The following is a list of the species found.

Titanotheriidæ—
- *Sivatitanops cotteri*, Pilgrim.
- *Sivatitanops birmanicum*, Pilgrim and Cotter.
- *Sivatitanops rugosidens*, Pilgrim.
- *Eotitanotherium lahirii*, Pilgrim.

Amynodontidæ—
- *Metamynodon cotteri*, Pilgrim.
- *Metamynodon birmanicus*, Pilgrim and Cotter.

Tapiridæ—
- *Indolophus guptai*, Pilgrim.
- *Chasmotherium birmanicum*, Pilgrim.

Anthracotheriidæ—
- *Anthracohus choeroides*, Pilgrim and Cotter.
- *Anthracothema pangan*, Pilgrim and Cotter.

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[1] *Rec. Geol. Surv. Ind.*, XLV, p. 107, (1915).

[2] Some Newly Discovered Eocene Mammals from Burma, *Op. cit.*, XLVII, p. 42, (1916). The Perissodactyla of the Eocene of Burma, *Pal. Ind.*, N. S., Vol. VIII, Mem. No. 3, (1925). The Artiodactyla of the Eocene of Burma, *Op. cit.*, N. S., Vol. XIII, (1928).

Anthracothema rubricæ, Pilgrim and Cotter.
Anthracothema palustre, Pilgrim and Cotter.
Anthracothema crassum, Pilgrim and Cotter.
Anthracokeryx birmanicus, Pilgrim and Cotter.
Anthracokeryx ulnifer, Pilgrim.
Anthracokeryx bambusæ, Pilgrim.
Anthracokeryx hospes, Pilgrim.
Anthracokeryx myaingensis, Pilgrim.
Anthracokeryx moriturus, Pilgrim.
Anthracokeryx (?) *lahirii*, Pilgrim.

Tragulidæ—
  Indomeryx cotteri, Pilgrim.
  Indomeryx arenæ, Pilgrim.

Primates—
  Pondaungia cotteri, Pilgrim.[1]

Age of Pondaungs.

As will be seen from the above list, the genera, with the exception of *Eotitanotherium*, *Metamynodon*, and *Chasmotherium*, are new, and it would be difficult, therefore, on the evidence of the fauna alone to be precise about the age. We, however, know that the Pondaung sandstone is later than the *Nummulites vredenburgi* (*N. acutus*) zone, that is, later than the 'B' division of the Middle Khirthar in the succession of north-west India. It is also older than the Yaw stage, which is equivalent to the Nanggulan stage of Java, and which is not represented by fossiliferous beds in north-west India. It will be seen that on external evidence the Pondaung sandstones fall between the Lutetian and the Ludian.

In considering the internal evidence of age, since all the species and most of the genera are new, we have to rely upon the general relationships and position in the evolutionary scale of the species described. While there is evidence according to Dr. Pilgrim that the fauna is more progressive than that of the Bridger beds of North America or the Irdin Manha formation of Mongolia, it is also noticeable that the anthracotheroids are more primitive than those of the Lower Oligocene of Egypt. The fauna is therefore later than Middle Eocene, and at least as old as Bartonian.

The titanothere genus *Sivatitanops*, according to Pilgrim, is to be distinguished from the Oligocene *Titanotheriinæ* by the strong development of the incisors, which have degenerated in the Oligocene family. Dr. Pilgrim thinks it to be a descendant of an early Eocene species of *Palæosyops*, and he regards it as in a stage of development very similar to that of such Upper Eocene genera *Telmatherium* and *Dolichorhinus*.

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[1] Described in *Pal. Ind.*, N. S., Vol. XIV, p. 12, (1927).

The species *Eotitanotherium lahirii* is compared with *E. osborni* Peterson from the Uinta B. 2 zone (Ludian) of the North American succession.

The Burmese amynodont *Metamynodon cotteri* is referred to the more typically Oligocene genus *Metamynodon*, which is found in the White River formation of North America. It is, however, Dr. Pilgrim tells us, a much more primitive form than *M. planifrons* by reason of the greater facial skull-length, the erect canines, and the larger incisors.

The tapiroid genus *Indolophus* appears to have as its nearest relative the Uinta genus *Isectolophus*, and the European Eocene genus *Lophiodon*.

The species referred somewhat doubtfully to *Chasmotherium* has an apparently near relation in *C. cartieri* from the Middle Eocene of Switzerland.

Anthracotheres.

The Pondaung anthracotheres, Dr. Pilgrim observes, are the most primitive types known of this family. There are no typical anthracotheres in the Irdin Manha beds of Mongolia nor do the Ardyn Gobo beds above the Irdin Manha formation in Mongolia contain any certain members of the family. The extraordinary predominance of anthracotheres gives the fauna a pecular character which differentiates it at once from any other fauna of like age. But in this respect it shows some resemblence to the fauna of the Lower Oligocene of Egypt and the Bugti beds of Baluchistan.

When compared with the later forms from Egypt and Baluchistan, the Pondaung anthracotheres exhibit primitive characters *viz.*, five cusps in the upper molars, long premolar series in several species, bunodont structure and absence of parastyle and metastyle in some species.

In summing up the evidence, Dr. Pilgrim says :—

> 'The Artiodactyls of the Eocene are invariably generalised forms; at this stage the characters which distinguish the various families in later epochs are either undifferentiated or are in such an early condition of development that they are unrecognisable or at any rate their significance is obscure.'

The following is a list of localities where fossils are found :—

Sheet 84 K/14.

Fossil localities.

(1) 6 furs. 8° E. by S. of Myaing hill (peak 1258).
Metamynodon birmanicus.

(2) 6½ furs. 9° W. by S. of Myaing hill—
Sivatitanops cotteri.
Metamynodon birmanicus.
Anthracothema pangan.

(3) 3 furs. north-west of Than-u-daw.
Anthracothema pangan.
Anthracokeryx myaingensis.
Anthracokeryx (?) *lahirii.*
Tragulid, gen. and sp. indet.

(4) ¾ mile W. S. W. of Pangan.
Anthracokeryx moriturus.

(5) ¼ mile west of Pangan.
Pondaungia cotteri.
Sivatitanops cotteri.
Anthracokeryx moriturus.
Anthracokeryx ulnifer.
Anthracokeryx birmanicus.
Indomeryx arenæ.

Sheet 84 K/10.

(6) 1 mile west of Bahin.
Sivatitanops cotteri.

Sheet 84 K/9.

(7) 1½ miles west of Mindezu.
Metamynodon cotteri.

(8) 1¼ miles west of Mindezu.
Anthracokeryx ulnifer.

(9) 1 mile E. S. E. of Sinzwe.
Sivatitanops rugosidens.
Indomeryx cotteri.

(10) 1½ miles south-west of Thadut.
Chasmotherium birmanicum.

(11) ¼ mile north-east of Kyawyaw, lying on Yaw beds.
Sivatitanops birmanicum.

(12) 1¼ miles north of Konywa.
Indolophus guptai.
(13) 1½ miles west of Mogaung.
Sivatitanops cotteri.

In 1922, Dr. Barnum Brown collected specimens from the Pondaung sandstone on behalf of the American Museum of Natural History.

CHAPTER VIII.

THE YAW SHALES.

Introductory.

The name 'Yaw stage' was given by me[1] in a former paper to the shale group which overlies the Pondaung sandstones in south Pakokku, and which was first studied in the Yaw river section. The thickness of the formation was estimated at from 1,600 to 2,000 feet. In the Yaw river section, they are a belt of soft blue shales, without much interbedded sandstones, and occupying long valleys or areas of low relief between the sandstones above and below. The lower boundary is sharp, and there is a sudden transition from the Yaw shale to massive Pondaung sandstone. Along the upper boundary there is a more gradual transition, the shales pass upwards into alternate strata of shale and sandstone, and these in turn into the more massive sandstones of the basal Pegu series. There is no evidence of any unconformity between the Yaw shale and the basal Pegus. The whole series of Yaw shales is richly fossiliferous.

Lithology.

In the country to the north-west of Pauk (sheet 84 K/7) the alternates of shale and sandstone which form the basal beds of the Pegus in the Yaw river section, have become massive sandstones, so that the boundary between the Pegus and the Yaws is here sharply defined. In the north of this sheet near Daungtaik, the Yaws contain gypsum, and the facies is more that of a shallow water deposit. Fossils in this area are broken and badly preserved, and no nummulites were found, although they abound in the country near the Yaw river. In this Yaw river section, the Yaws consist of blue shales with occasional bands of limestone and of calcareous sandstone. There is a strong lithological resemblence to the Padaung clays of the Ngahlaingdwin area in north Minbu, and of the Man river near Ngape in south Minbu, but the Padaung clays are Chattian, while the Yaws are Priabonian in age.

In sheet 84 K/5, Capt. F. W. Walker describes the Yaws as consisting for the most part of bluish gray shale, composed of

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[1] *Rec. Geol. Surv. Ind.*, XLIV, p. 52, (1914).

Yaws of north Pakokku.

fine argillaceous matter which weathers to a soft clay. A few thin bands of sandstone are found in the lower part of the formation. More noticeable are certain bands of shelly conglomerate about six inches thick, which owing to the much slower rate of weathering, stand out conspicuously from the shale. In these shelly bands the majority of the fossils collected by Capt. Walker occurred. Calcareous bands showing cone-in-cone structure are occasionally found, and also brownish bands of septarial matter. Close to the base of the formation there are bands of impure coal or carbonaceous shale, usually only a few inches thick, and which are very constant, forming a regular outcrop. In the south part of the sheet the Yaws are fairly rich in fossils. North of lat. 22°, the shelly conglomerate bands fail, and in the sheet to the north (84 J/8) the few fossils found in the shale are badly preserved. The Yaws attenuate considerably as they are traced northwards. A bed containing fish remains was seen by Capt. Walker in several sections near the base of the Yaws. The best section is one near Kanthet (84 J/8).

Step-faults.

Step faulting is common in the Yaws in sheet 84 K/5. There are some good sections of these faults near Kyawtha. East of the Pondaung, the Yaws are greatly squeezed and contorted. Springs are common in the Yaws of the Kyaw valley.

Upper boundary.

The upper boundary of the Yaws in sheet 84 K/5 is marked by a belt of alternating sandstones and shales. The thickness of the Yaws in this area, except where they are squeezed, is estimated at 1,800 feet, but it has been observed above that there is attenuation as one traces the formation northwards.

Yaws of Maw valley.

There is an interesting occurrence of Yaws along the east margin of the valley of the Maw river between Tillin and Gangaw. Here the Maw gravels rest upon shaly beds. In several localities north of Tilin the shales contain upper Cretaceous fossils (*Orbitoides apiculata*, etc.) see *ante*. There is however a tract east of Shwekondaing and Semindaw where the shales immediately underlying the Maw gravels contain the typical Yaw species *Nummulites yawensis*, Cotter and *Gosavia humberti* (D'Arch. and Haime) (=*Voluta birmanica*, Dalton). *Operculina canalifera* is also found in these beds. There is a fossil bed with these species about one mile south-west of Yeshin.

It will be shown below that the Maw gravels contain Lower Siwalik vertebrate fossils as well as a Middle Siwalik fauna.

As the basal Irrawaddy sandstone shows a fauna not older than the Dhok Pathan zone of the Middle Siwalik, it is clear that the Maws include in their lower parts beds equivalent to part of the Pegus. The Yaw shales occur as a downward continuation. The section may be compared with that of the Myaing anticline, which will be described below. The point to observe is that both in the Myaing anticline and here in the Maw valley, freshwater sandstones of Irrawaddy type pass downwards into upper Eocene (Yaw stage) beds, without the intervention of marine Pegus.

In this Maw valley area, the Yaw shales are practically indistinguishable (except for their fossil contents) from the Laungshe basal beds on which they abut. Possibly, if the country were bare and open, as is the case in north-west India, the two stages might be readily separated. But this Maw valley is a well-forested area, with a good soil-cap, and the shales are concealed over large tracts. There is no doubt also that the Yaws and the Laungshes resemble each other sufficiently to render a distinction by lithology extremely difficult. The Yaws are brought into juxtaposition with the Laungshes by a strike-fault, and the Maw gravels rest with nonconformity upon them, but without any discordance. The beds are much crumpled. *N. yawensis* and *Operculina canalifera* were found one mile E. S. E. and also one mile E. N. E. of Semindaw.

Other localities where Yaw beds are believed to be exposed (from an examination of the fossil contents) are :—

1¼ miles east of Shwekondaing; 1 mile south-east of Semindaw; 1 ml. 1 fur. south-east of Semindaw; 1¾ miles W. S. W. of Tawma.

The presence of the Yaw beds was not fully proved until the specimens were examined in office on return from camp. This sheet was mapped by Mr. B. B. Gupta, but he did not map the Yaws separately from the Laungshes, as the boundary could not be seen clearly owing to the forest growth.

The Yaws have been mapped in from a consideration of the position of the fossil-beds both of the Laungshes and of the Yaws, and while the line may require some slight correction when the map is revised in the field, its general outline is probably fairly accurate.

Sheet 84 K/9 was also mapped by Mr. B. B. Gupta. Here the Yaws are attenuating out to zero about 2 miles west of Legan, but they thicken again to the south-east.

Yaws north-west of Myaing.

Some bryozoa were collected some three furlongs W. N. W. of Yegyaw, which Mr. Gupta refers to the genera *Lepralia* and *Collopora*. As in the sheet to the west, the basal Yaws are characterised by coal-seams. The best seam is not over three feet thick.

In sheet 84 K/14, around Suwin, the Yaw shales are of similar facies to the Yaws in the western adjoining sheet. From the Seikche *chaung*, *Cardium kanleanum*, Cotter and *Gosavia humberti* (D'A. and H.) were collected, and in a stream 1¼ miles W. S. W. of Thayetkwa, *N. yawensis*, *O. canalifera*, *Orthophragmina sella*, *Cardium thetkegyinense* and *Cypraedia birmanica*.

Change in facies.

In the north-west quadrant of sheet 84 K/14, there is a tract over which the Yaw shales are of an earthy and rather arenaceous facies with fossil wood. They are thus rather difficult to trace, and their upper and lower boundaries are no longer sharp. They are here apparently a shallow water deposit. To the south in the Myaing anticline south of Myaing, the Yaws are more shaly and of a more marine type, but fossils are still rare. Of those that were collected, the following species were identified from the Yaws south of Myaing:—

Myaing area.

Orthophragmina sella, D.'Arch., *Gosavia humberti*, D.'Arch., *Cypraedia birmanica*, Vred., *Cardium thetkegyinense*, Cotter, a nummulite probably *N. yawensis*, Cotter, and *Operculina canalifera*.

Above and below the Yaws of this area, the beds are freshwater. Below are the freshwater facies of the Pondaung sandstones with a vertebrate fauna. Above are the Irrawaddy sandstones, and intervening between the basal Red Bed of the Irrawaddies and the Yaw shales, are about 1,000 feet of fluviatile beds which may be Pegu, or an upper extension of the Yaws.

It is, however, to be noticed that the Pegu formation is either absent or greatly reduced. This is very surprising when one realises that it is only thirteen miles in a south-westerly direction from the southern tip of the Myaing anticline to the northern end of Yenangyat, where the Pegus underlie the Irrawaddy sandstone, and are over 4,000 feet thick. There are no Yaws visible in the Yenangyat anticline, and no Pegus in that of

Myaing. They are, however, on different lines of strike, and this is probably the reason for the sharp contrast.

Velates bed.

Mr. H. S. Bion mapped the country to the south of the Yaw river, in which Yaw shales are exposed. South of lat. 21° 5′, he found *Velates perversus* (Gmelin) (=*schmideliana Ramauct*) at the top of the Yaws. This *Velates* bed could not be traced north of this latitude, since the bed changes its facies and becomes a sandstone. This sandstone must then be mapped with the overlying Pegu sandstones; thus the lithological boundaries transgress across the faunal lines.

Yaws of Ngahlaingdwin.

Further south in sheet 84 L/5, H. S. Bion sub-divides the Yaws into two groups, following the grouping adopted by C. Porro.[1] The upper Yaws consist of alternations of sandstone and shale with fossils; the lower Yaws are mainly yellow sandstones with siliceous layers, outcropping in sharply defined beds, with coal or carbonaceous shale at the top. Foraminifera and corals are abundant in the upper division; amongst these are *Nummulites yawensis* and *Orthophragmina sella*. Bion estimates the thickness of the Yaws at from 1,500 to 2,000 feet.

Mr. S. R. Rau's section.

In the southern half of sheet 84 L/5 and the north of 84 L/6, the Ngahlaingdwin anticline has attracted much attention owing to the hopes once entertained of developing this area into an oilfield. This tract was mapped by Rao Bahadur Sethu Rama Rau, and in the Salin river, which traverses the middle of sheet 84 L/5, he gives the following succession westward in descending order from the boundary of the Irrawaddy sandstones, through the Pegus and Yaws to the Pondaung sandstone :—

20 Ferruginous pebbly conglomerate	Basal Irrawaddy beds.
19 Conglomerate and sandstone	13 to 19, Upper and Middle Pegus.
18 Shales and sandstones with *Batissa birmanica*, Vred.	
17 Limestones with *Arca submultiformis*, Vred., *Telescopium* sp.	
16 Gritty sandstones and conglomerates	
15 Sandstones	
14 Poor seams of coal	
13 Shales and sandstones	

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[1] C. Porro, Geology of the country near Ngahlaingdwin, *op. cit.*, XLV, p. 249, (1915).

12 Padaung clays divisible into three zones :— Upper beds, rich in *Tritonidea martiniana* (Nœtl.), *Melongena præparadisiaca*, Vred., *Tellina*, etc. Middle beds, with *Flabellum*, and *Dendrophyllium*. Lower beds, with *Ostræa*	12, Padaung clay stage.
11 Sandstones and limestones, here barren of fossils 10 Impure coal 9 Sandstones, here barren	9 to 11, Shwezetaw sandstones.
8 Limestones with *Velates perversus*, and *Orthophragmina sella* 7 Shales 6 Limestones with *Nummulites yawensis* 5 Sandstones and shales 4 Thick impure beds of coal	4 to 9, Yaw stage.
3 Petroliferous sandstones with hydrogen sulphide springs 2 Unfossiliferous sandstones 1 Hard sandy limestone forming top of Dudawtaung	1 to 3, Pondaung sandstones.

Yaws south of Ngahlaingdwin.

In sheet 84 L/6, to the south of Ngahlaingdwin, Mr. E. L. G. Clegg describes the Yaws as very variable in thickness and character. South of the mapped area, the thickness is only 300 to 400 feet. Around Kanbauk, the thickness has increased to 2,500 feet, and the beds are alternations of sandstone and shale. Coal occurs here in the upper beds, and is underlain by a bed containing a large *Ampullina*. The 2,500 feet of Yaws are made up of three main beds of shale separated by two bands of sandstone, which in places are of a fawn to green colour, and in which thin coal lenticles and false-bedding are common. The disappearance of the Yaw stage to the south of the mapped area is due to overlap by the Shwezetaws or basal Pegus.

The *Ampullina* found by E. L. G. Clegg is probably that described by L. V. Dalton[1] as *A. grossa*, Desh., a species found in a horizon in south Minbu which is well below the *Velates* bed.

Fauna.

The fauna of the Yaw stage is not thoroughly known. Owing to the death of Mr. E. W. Vredenburg, many of the gastropoda remain as yet undescribed. The following families have been untouched :—*Purpuridæ, Tritoniidæ, Cassididæ, Doliidæ, Strombidæ, Cerithidæ*. The description of the remaining gastropod families form part of a series of papers on Indian Tertiary Gastropoda, which appeared in the *Records of the Geological Survey of India*, Vols. LI, LIII, LIV, and LV.

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[1] L. V. Dalton, Geology of Burma, *Quart. Journ. Geol. Soc.*, LXIV p. 637, (1908).

Foraminifera.

So far, only three species of foraminifera have been collected from the Yaw stage in north Minbu and Pakokku; they are:—

Nummulites yawensis, Cotter.[1]

Orthophragmina (*Discocyclina*) *sella*, D'Arch.

Operculina sp., cf. *canalifera*, D'Arch.

N. yawensis is very abundant in the Yaw stage in the country near the Yaw river; it is found in the south of the Myaing anticline at the top of the Yaws, in the Zaha *chaung*,[2] in the Ngahlaingdwin area, in the Yaws underlying the Maw gravels east of the Tilin-Gangaw valley near Shwekondaing, and in many other places. It has not been found at any other horizon except the Yaw stage; it does not occur in the tertiaries of north-west India, the Upper Eocene being there very poorly developed. It appears to be a reliable zone fossil.

Discocylina sella, D'Arch. is a small papyraceous megaspheric form of 7 to 8 mms. diameter, and about 1¼ mm. thick. It corresponds with a form from Borneo, figured by Miss Irene Provale,[3] and identified by her with D'Archiac's species. This species is found in the Zaha *chaung* (*see* above), in the Myaing anticline, and in various other localities, usually in company with *N. yawensis*.

The *Operculina* of the Yaw stage has been identified by L. V. Dalton[4] with D'Archiac and Haime's species *O. canalifera*. *O. canalifera* is, however, a Ranikot form,[5] occurring both in north-west India and in Tibet[6] at this horizon. If the Burmese form is really the same species as that of the Ranikot stage, it must be admitted that *O. canalifera* ranges from the lower to the upper Eocene.

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[1] See *Rec. Geol. Surv. Ind.*, XLIV, p. 77, (1914).

[2] For position of Zaha *chaung*, see C. Porro's paper and map in *Rec. Geol. Surv. Ind.*, XLV, p. 249, (1915). The Zaha *chaung* is also mentioned in H. Douvillé's paper in *Bull. Soc. Geol. Fr.*, (1905) p. 452. See also *Rec. Geol. Surv. Ind.*, XLIV, p 77, (1914) where locality D is about 5 miles N. of Zaha *chaung*.

[3] Irene Provale: Di alcune Nummulitine e Orbitoidine dell' Isola di Borneo, *Riv. Ital. di Paleont.*, XIV, p. 55.

[4] *Quart. Journ. Geol. Soc.*, LXIV, p. 633, (1908).

[5] *See* W. L. F. Nuttall, *Geol. Mag.*, LXIII, pp. 117 and 498, (1926).

[6] *Rec. Geol. Surv. Ind.*, LIX, p. 414, (1926).

Gastropod fauna.

The following is a list of the Gastropoda of the Yaw stage :—

Genotia birmanica, Vred.[1] (Thetkegyin, south-west quadrant, sheet 84 K/7 ; Kyaukkwet *chaung*, 84 K/10). This form is closely related to *G. jogjacartensis*, Martin from the Upper Eocene of Nanggulan in Java.[2]

Genotia garrowi, Vred.[1] (Thetkegyin, Kyaukkwet *chaung*).

Conus (*Lithoconus*) *gracilispira*, Bœttger, (Thetkegyin, Kyaukkwet *chaung*). This form was first described from the Upper Eocene of Borneo.

Gosavia humberti (D'Arch. and Haime) (Very common throughout the Yaws wherever they are fossiliferous, Thetkegyin, etc.) D'Archiac and Haime figured the type from the Laki stage of Sind. The Burmese form was described as *Voluta birmanica* by Dalton[3] ; as *Gosavia birmanica* by Pilgrim and Cotter [4] ; and as *Aulica birmanica* by Vredenburg[5], but L. R. Cox thinks[6] that the species belongs to the genus *Gosavia* and that it is identical with the Laki species of D'Archiac and Haime.

Harpa (*Eocithara*) *birmanica*, Vred.[5] (Thetkegyin). This species is a close relative of *Harpa mutica*, Lamarck from the Middle Eocene of the Paris basin.

Marginella orientalis, Vred.[5] This form is found at Thetkegyin in the Yaw stage, and at Myaungu on the main road from Salin to Sidoktaya, where it occurs in the Padaung clay horizon.

Athleta (*Neoathleta*) *rosalindæ*, Vred.[3] (Thetkegyin). This shell is related to *Voluta cithara*, Lamarck, an Eocene form from the Paris basin.

Athleta pernodosa (Dalton).[3] This species has not been found in the Yaws of the Pakokku district, but is recorded by Dalton[3] from beds presumably of Yaw age in south Minbu.

Athleta (*Volutospina*) *augustæ*, Vred.[5] This species is found at Thetkegyin and in the Zaha *chaung* area and south-west of Kywe-u (sheet 84 L/5, extreme south). It is related to *Voluta elevata*, Sow. from the Eocene of the Paris basin.

Athleta (*Volutospina*) *annandalei*, Vred. (Thetkegyin). Resembles V. *elevata*, Sow. from the Eocene of the Paris basin.

Athleta (*Volutocorbis*) *archiaci*, Dalton[3 & 5]. This shell is recorded by Dalton from the Yaw horizon in south Minbu, but occurs also in Pakokku between the 31st and 32nd milestone, at about 31 mls. 2 furs. on the Yaw-Pasok road. It is the same species, according to Vredenburg, as *Volutocorbis ickei*, Martin from the Upper Eocene of Java. Dalton's name, however, has the priority.

Volutilithes arakanensis, Vred.[3] This is found in the Yaws of the Kyaukkwet *chaung* (85 K/10). It bears a close resemblance to a Javanese form doubtfully referred by Martin to *V. junghuhni*.

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[1] E. Vredenburg, Indian Conidæ, *op. cit.*, LIII, p. 132, (1921).

[2] *Samml. des geol. Reichs-Museums in Leiden*, New Ser., Vol. II, p. 111.

[3] *Quart. Journ. Geol. Soc.*, LXIV, p. 632, (1908).

[4] *Rec. Geol. Surv., Ind.*, XLVII, p. 44, (1916).

[5] *Op. cit.*, LIV, p. 269, (1923).

[6] *Trans. Roy. Soc. Edin.*, Vol. LVII, Pt. I, (No. 2), p. 57, (1931).

Scaphelta humilis, Vred.[2] (Thetkegyin).

Clavilithes cossmanni, Vred.[1] (Kyudaw *chaung* east of Pasok, sheet 84 K/3). This shell is closely related to *C. songensis*, Martin from the Upper Eocene of Java.

Clavilithes songoensis, Martin[1] (Yaw stage W. N. W. of Ngapya, in north half of sheet 84 L/5).

Semifusus heroni, Vred.[1] (Thetkegyin). This species is closely related to *S. timorensis*, Martin from the Miocene of Timor and Java.

Lacinia indica, Vred. [2 & 1] (Kyudaw *chaung* east of Pasok, 84 K/3). This is related to *L. sangiranensis*, Martin.

Velates perversus (Gmelin) = *V. schideliana*, Chemnitz. This species was originally recorded from Burma by F. Noetling, but the exact[3] locality was not stated. Later, G. de P. Cotter found specimens in south Minbu,[4] and subsequently Rao Bahadur S. Sethu Rama Rau and H. S. Bion found specimens in the topmost part of the Yaw stage in the Ngahlaingdwin area (84 L/6) and in the country to the north. H. S. Bion remarks that no specimens of *Velates* were found north of lat. 21° 5′. In India, this species is found from the Ranikot to the Khirthar, and in Europe from the Lower to the Upper Eocene.

Cyprædia birmanica, Vred.[5] This species was figured by L. V. Dalton (*Op. cit.*, p. 629 and Pl. LVII, figs. 7 and 8) under the name of *C. elegans*, Defrance. Dalton regards it as post-Eocene, but in Burma it a very typical Yaw stage fossil, and is not found in later beds. Vredenburg thinks that it may be an adult specimen of a species figured by Martin as *C. conigera*.

Ampullina cf. *grossa*, Deshayes. It was noted above that E. L. G. Clegg found a large *Ampullina* apparently identical with that figured by L. V. Dalton (*op. cit.*) from south Minbu. Mr. Clegg's specimens came from the Yaws near Kanbauk in sheet 84 L/6.

Rimella sp. *indet.*, *Hindsia* sp. *indet.*, *Natica* spp. indet.,[6] and *Sigaretus* sp. indet., all from the Thetkegyin area, are some of the undescribed gastropoda which still await examination.

Lamellibranch fauna.

The lamellibranchiata of the Yaw stage were described by me in 1923.[6] The following is a list of the species identified:—

Solen manensis, Cotter.

Corbula subexarata, D. Archiac, var. *lituus*. This species is common also in the Laki and Khirthar of India.

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[1] E. Vredenburg, Indian Tertiary Gastropoda, IV., *op. cit.*, LIV, p. 243, (1923).

[2] E. Vredenburg, Indian Comdæ, *op. cit.*, LIII, p. 132, (1921).

[3] F. Noetling, Note on the Occurrence of *Velates schmideliana* in India and Burma, *op. cit.*, XXVII, p. 103, (1894).

[4] G. de P. Cotter, The Pegu Eocene Succession in Minbu, *op. cit.*, XLI, p. 221, (1912).

[5] E. Vredenburg, Classification of Cypræidæ, *op. cit.*, LI, p. 118, (1920).

[6] The Lamellibranchiata of the Yaw stage, *Pal. Ind.*, N. S., Vol. VII, Mem. No. 2, (1923).

Corbula paukensis, Cotter. A very small species very close to *C. watumurensis* from the Java Eocene.

Tapes birmanicus, Cotter. A wide-spread species in the Yaw stage from north Minbu to Pakokku.

Meretrix yawensis, Cotter. Close to *M. bottgeri*, Martin from the Java Eocene.

Meretrix agrestis, Cotter. This may be identical with a Borneo species figured by Bottger as *Cytherea heberti*, Desh., but the identity with the Paris species is doubtful.

Blagraveia (?) *yethama*, Cotter. This species was referred by me originally to the genus *Sunetta*. It has not, however, the shape of a *Sunetta* and recalls somewhat the shape of a *Clementia*. Most of all does it resemble the genus *Blagraveia* founded by L. R. Cox in 1931.[1]

I consulted Mr. Cox upon the generic identification, and he wrote 'It seems most probable that *Sunetta yethama* does belong to *Blagraveia*, although it is also very much like *Clementia*. I am now quite convinced that *Blagraveia* does belong to the *Veneridæ*.' It is related to a species described by Bottger from Borneo under the name of *Venus sulcifera*.

Venus paskoensis, Cotter. This belongs to the group of *Venus præcursor* from the Tongrian of Italy.

Tellina nanggulanensis, Martin. This species is widely spread in the Yaw stage, and is identical with Martin's species from the Upper Eocene of Java. There are related forms in Borneo from beds of the same age.

Tellina (*Colpopagia*) *tazuvensis*, Cotter. A relative of *Arcopagia colpoides* from the Paris Eocene and ancestral to *T. grimesi* from the Pegus of Burma.

Tellina salinensis, Cotter. From the Salin *chaung* in sheet 84 L/5.

Cardium kanleanum, Cotter. A globular *Cardium* and one of the largest species known. *C. gigas* from the Paris Eocene is of similar size but more elongate.

Cardium thetkegyinense, Cotter. One of the commonest species of the Yaw stage. It resembles *C. eduliforme* from Borneo Eocene beds.

Cardium cotteri, Cox[2] (=*C. ambiguum*, Sow.) Recorded by Rao Bahadur S. Sethu Rama Rau from Yaws north of Ngahlaingdwin (84 L/6).

Pinna sp. indet. A broken species from the Thetkegyin area, resembling *P. margaritacea*, Lamk.

Ostræa minbuensis, Cotter. A longirostriform *Ostræa* found in the Yaws about three miles east of Pasok (sheet 84 K/3).

Chlamys sp. cf. *multistriata*, Desh. Poorly preserved. Found in the Yaw river section, about 2 miles east of Tazu (sheet 84 K/7).

Leda silvestris, Cotter. From Kyutaw *chaung*, 2½ miles east of Pasok.

The above list of the fauna of the Yaw stage is complete, so far as the north Minbu-Pakokku area is concerned, but, as has been noted, there is still some undescribed material.

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[1] L. R. Cox, New Lamellibranch genera from the Tethyan Eocene, *Proc. Malac. Soc. London*, New Ser., XV, p. 129, (1931).

[2] *See* L. R. Cox in *Trans. R. Soc. Edin.*, LVII, Pt. I, (No. 2), p. 82, (1931).

In addition to the lists of fossils from the Burmese Eocene given in the preceding pages, we may perhaps summarise briefly the forms found in south Minbu and north Thayetmyo, which have been identified in former papers by L. V. Dalton,[1] by myself,[2] and by E. L. G. Clegg.[3]

Yaw fauna in south Minbu.

In south Minbu, the 'G' bed described by myself is without doubt the same horizon as the Yaw stage of Pakokku. It contains the following species:—

Velates perversus (Gmelin).
Cardium cotteri, Cox (=*C. ambiguum*, Sow.)[4]
Corbula subexarata, D'Arch.
Meretrix cf. *sulcataria*, Desh. (=*Venus subovalis*, D'Arch.)
Cypraedia birmanica, Vred. (=*C. elegans*, sec. Dalton and Cotter.)
Athleta (*Volutocorbis*) *archaici*, Dalton.
Gosavia humberti (D'Arch. and Haime).

The remaining identifications of fossils from the 'G' bed need further study. The fauna, however, corresponds very well with that of the Yaw stage of Pakokku, and the *Velates* bed is evidently the same as that of Ngahlaingdwin in north Minbu.

Kyet-u-bok bed.

The Kyet-u-bok band has been traced for over a distance of 10 miles to the S. S. E. of Kyet-u-bok by E. L. G. Clegg, and is found also in the country to the west in a synclinal basin shown in the map accompanying his paper. Its fauna, the list of which is compiled from my own and E. L. G. Clegg's paper and that of L. V. Dalton may be summarised as follows:—

Orthophragmina (*Discocyclina*) *omphalus*, Fritsch. A species larger than *O. sella*, and figured from the Borneo Upper Eocene by Fritsch, and by H. Douvillé.

Gypsina globulus, Reuss. Ranges from Eocene beds in Christmas Island to present day.

Nummulites beaumonti (?) The identification needs confirmation; the specimens are poorly preserved. L. D. Stamp [*Geol. Mag.*, LIX, p. 494, (1922)] says that this species is *N. yawensis*, Cotter.

Nummulites obesus, D'Arch. Recorded by E. L. G. Clegg.

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[1] L. V. Dalton, Geology of Burma, *Quart. Journ. Geol. Soc.*, LXIV, p. 612, (1908).

[2] G. de P. Cotter, Pegu-Eocene Succession in Minbu, *Rec. Geol. Surv. Ind.*, XLI, p. 221, (1912).

[3] E. L. G. Clegg, Overlap in Ngape area, *op. cit.*, LXVI, p. 250, (1932).

[4] *See* L. R. Cox in *Trans. R. Soc. Edin.*, LVII, Pt. I, (No. 2), p. 82, (1931).

Orthophragmina (Discocylina) papyracea, Boub. var. *javana*, Verb. A large *Orthophragmina*, up to half a crown in size. Collected by W. Theobald from Thayetmyo, and later by E. L. G. Clegg.

Operculina cf. *canalifera*, D'Arch. Recorded by L. V. Dalton and E. L. G. Clegg.

Gosavia humberti, D'Arch. As has been noted above this species is very abundant throughout the Yaw stage, and also characterises the Khirthar of India.

Athleta (Volutospina) annandalei, Vred. Also in Thetkegyin area, Yaw stage.

Cardium thetkegyinense, Cotter. Very abundant throughout the Yaws.

Cardium subfragile, Bottger. Yaw stage of Pakokku and Borneo.

Tellina (Colpopagia) tazuiensis, Cotter. Yaw stage of Pakokku.

It may be noted that *Nummulites yawensis* is possibly present and the fauna must be correlated with that of the Yaw stage of Pakokku. The mapping of the country from north to south Minbu confirms this correlation, but owing to dense forest, and to the failure of the Padaung clay horizon as a sharply marked unit in the extreme south of Minbu, the continuous tracing of beds has been rendered somewhat difficult.

CHAPTER IX.

THE PEGU SERIES OF THE WESTERN OUTCROPS.

The post-Eocene beds of Burma have been divided by W. Theobald into a lower marine or estuarine series of beds which he termed the Pegu series, and an upper, which was in his original paper named the Fossil Wood group, and which is mainly a fresh water deposit.[1]

Meaning of term "Pegu Series".

The term 'Pegu series' was adopted by F. Noetling, when he mapped the Yenangyaung oilfield, with much the same meaning as that originally given to it by W. Theobald, but Noetling replaced the term 'Fossil Wood group' by a new name 'Irrawaddy series' to denote the freshwater beds above the marine post-Eocene in the Yenangyaung and Yenangyat areas.[2]

Subsequent geologists have followed this practice, discarding the term Fossil Wood group for that of Irrawaddy series, and retaining the term Pegu series, and these terms will be used in this memoir.

Difference in meaning of 'Fossil Wood Group' and 'Irrawaddy Series'.

Since fossil wood, although characteristic of Pliocene beds in Lower Burma, where W. Theobald's work was done, is, in Upper Burma, found at many horizons both in the Irrawaddy series, the Pegu series, and the Eocene, the term 'Fossil Wood group' is hardly suitable to designate the freshwater beds above the Pegus, and it was probably mainly this consideration which influenced later geologists to discard Theobald's term in favour of that adopted by Noetling.

Moreover the two terms do not appear to be quite synonymous. I have elsewhere discussed this question at some length[3], and have shown that while W. Theobald in 1873 and, following him, M. Stuart in 1910, included in the Fossil Wood group certain shallow water marine sands known as the Mogaung or *Turritella* sands, which lie at the base of the freshwater series, a revision was adopted in 1912 by M. Stuart, after discussion with his colleagues, whereby the

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[1] *Rec. Geol. Surv. Ind.*, II, pp. 79, 80, (1869). See also *Mem. Geol. Surv. Ind.*, *X*, Pt. 2, (1873).

[2] *Rec. Geol. Surv. Ind.*, XXVIII, p. 76, (1895).

[3] Note on the Geology of Thayetmyo *op. cit.*, LIV, p. 103, (1922).

Turritella sands of Thayetmyo, and the Akauktaung beds of Henzada were tabulated as uppermost Pegus, thus restricting the grouping of the freshwater beds above, so as to comprise *only* strictly freshwater deposits. It was felt at the time that this grouping would be more harmonious with that adopted in Upper Burma by Noetling, Grimes, Pascoe, myself, and others.

At the same time, the freshwater beds of Lower Burma received the name 'Irrawaddy series' on the view that they were of the same age as the Irrawaddy series of Upper Burma.

Akauktaung stage.

Some doubt exists as to the exact age of the Akauktaung beds of Henzada, but if we regard them as older than Pontian, *i.e.*, Vindobonian, they must be older than the Irrawaddy beds of the type area in Yenangyaung, and they therefore fall more naturally into the Pegus as their topmost member.

The Irrawaddy beds therefore are probably homotaxial with the Siwaliks of India, provided we exclude the Kamlials from the Siwaliks, as I have suggested in a recent publication.[1] The Pegu series is then the exact equivalent of the Gaj and Nari stages of India.

Noetling's sub-divisions.

The sub-division of the Pegus was attempted by W. Theobald, but the imperfect maps of his day and the rudimentary knowledge of the palaeontology of the series rendered his classification doubtful when applied to sections in Upper Burma. Subsequently, F. Noetling made an elaborate sub-division into stages and zones of the Pegu series, but his work gradually came to be looked on with grave suspicion.

When work on the Burma oilfields was resumed by Sir E. H. Pascoe, then a new recruit to the Geological Survey, in 1905, it was Noetling's stratigraphical zoning and fossil descriptions which we mainly depended upon. I joined Sir E. H. Pascoe in 1905 and, up till 1909, we were engaged in mapping anticlinal areas, where the full section of the Pegus was not exposed.

In 1909, I examined a complete section along the Man river near Ngape in south Minbu, and subsequently described the succession from the top of the Pegus to the base of the Eocene.

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[1] *Mem. Geol. Surv. Ind.*, LV, p. 99, (1933).

[2] The Pegu-Eocene Succession in the Minbu District near Ngape. *Rec. Geol. Surv. Ind.*, XLI, p. 221, (1912).

Work in Ngape and Henzada.

Meanwhile Dr. M. Stuart had, in Prome and Henzada districts of Lower Burma, gone over the ground originally mapped by W. Theobald in the 'sixties' of last century, and made a fresh survey and revision of his work. Dr. Stuart's attention was mainly directed to the Upper Pegus, which are highly fossiliferous in Lower Burma. The work of Stuart and myself and the fossil collections we made were studied by E. Vredenburg, who was then Palæontologist to the Geological Survey of India. Writing in 1920,[1] E. Vredenburg published his conclusions upon the sub-division of the Pegus, and his subdivision of the series, which summarises the work of our party in Burma, is that which is adopted here. Vredenburg at the same time exposed the unsoundness of Noetling's 'zone' and revised his work on the gastropoda. He did not, however, take up the study of the lamellibranch fauna, with the exception of selected genera such as *Ostræa* and *Cyrena.*

Revisions of Vredenburg.

Vredenburg's sub-divisions.

Vredenburg in a subsequent paper in the same volume of the *Records*[2], published a scheme of sub-division of the Pegu series into stages, with a table of equivalent stages in Java and north-west India. It is briefly given below :—

Age.	Burma.	Java.	North-west India.
Pleistocene .	Plateau-Gravel .	Kendeng beds .	Raised beaches, etc.
Pliocene . .	Irrawaddy series, (upper part).	Sonde series .	Upper Siwalik and Gwadar stages.
Pontian . .	Irrawaddy series, (lower part). Akauktaung beds, in part.	Odeng beds . .	Middle Siwalik and Talar stages.
Vindobonian .	Perhaps Akauktaung beds, in part.	Tji Lanang series .	Lower Siwalik and Manchar.
Burdigalian .	Pyalo stage . .	Njalingdun series .	Bugti beds, Murree beds, Upper Gaj beds.
Aquitanian .	Kama stage .	Rembang series .	Lower Gaj.
Chattian . .	Singu stage . .	....	Upper Nari beds.
Stampian . .	Sitsayan stage .	....	Lower Nari beds.
Lattorfian .	Shwezetaw stage .	....	Mula Pass beds (in part).

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[1] Results of a Revision of Some Portions of Dr. Noetling's Second Monograph on the Tertiary Fauna of Burma, *op. cit.*, LI, p. 224 (1920).

[2] Marine Fossils of the Garo Hills, *op. cit.*, LI, p. 328, (1920).

Modifications of Vredenburg's scheme.

In 1922, I recommended the abandonment of the term 'Sitsayan' and its replacement by that of 'Padaung' to denote the stage below the Singu beds,[1] on the ground that the term had been adopted by Vredenburg from my own previous paper on the Ngape section where I had described the Padaung beds as probably to be correlated with the Sitsayan shales of Theobald. I suggested in my later paper that the fossil-horizon in the Ngape section and the belt of clays containing this fauna should derive their name from the village of Padaung in that area, since the correlation with the original Sitsayan shales of south Thayetmyo was doubtful.

Subsequent mapping in south Thayetmyo by Mr. E. L. G. Clegg[2] indicated that the Sitsayan shales of Theobald are a larger group than the Padaung clay, representing both the Padaung stage (='Sitsayan' stage of Vredenburg) and the Shwezetaw stage below.

Stratigraphical position of Akauktaung beds and Turritella sands.

In my paper above quoted, I pointed out that the Irrawaddy series in Thayetmyo are mainly gravels, if we exclude the *Turritella* sands at their base, and place the latter in the Pegus, where they most naturally belong. This course was followed by H. S. Bion, whose map was published posthumously with my paper. E. L. G. Clegg, having mapped the country between Thayetmyo and Minbu districts, was able[3] to confirm the view that this horizon is the correct boundary between the Irrawaddy series and the Pegus according to the usage adopted in Upper Burma, and it follows that the *Turritella* sands and their representatives the Akauktaung beds of Henzada must also be placed in the Pegus as their uppermost stage. This however involves a change from Theobald's original scheme, since he included the *Turritella* sands in the Fossil Wood group as their basal member. The change is necessary, because of two facts, first that the natural boundary line between the two series from south Pakokku to Thayetmyo is the passage from shallow marine to freshwater beds, and secondly that the fossil evidence seems to point to a Vindobonian age for the Akauktaungs, while the basal Irrawaddy beds of the type area (Yenangyaung) are not older than Pontian.

In the following pages, Vredenburg's[4] scheme of sub-division will be adopted with the above modifications, *viz.*, the replacement of the term

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[1] *Rec. Geol. Surv. Ind.*, LIV, p. 115, (1922).

[2] *Op. cit.*, LVIII, p. 45, (1925).

[3] *Loc. cit.*

[4] World Petroleum Congress, Pre-Print No. 169, (1933).

'Sitsayan' by that of 'Padaung', and the removal of the Akauktaung stage to the top of the Pegu series.

Mr. G. W. Lepper[1] in 1933 published a scheme of sub-divisions of the Pegu series, which has been adopted by the Burmah Oil Co.'s geological staff. It is as follows :—

G.W. Lepper's scheme of sub-division.

	Mio-Pliocene	Irrawaddy series . . .	. 5,000 to 10,000 ft.
Pegu series .	Miocene .	Obogon alternations .	. up to 3,000 ft.
		Kyaukkok sandstones .	. up to 5,000 ft.
		Pyawbwe clays . . .	. up to 3,000 ft.
		(unconformity)	
	Oligocene .	Okhmintaung sandstones.	. 0 to 4,500 ft.
		Padaung clays . . .	. up to 2,500 ft.
		Shwezetaw sandstones .	. 2,000-4,000 ft.

The two schemes compared.

This scheme does not differ very markedly from that of the Geological Survey of India, in which the Miocene is sub-divided into three stages, the Akauktaung, Pyalo, and Kama, corresponding to the Obogon, Kyaukkok, and Pyawbwe; and the Oligocene into three stages, the Singu, Padaung and Shwezetaw, corresponding with the Okhmintaung. Padaung, and Shwezetaw.

Mr. Lepper marks an unconformity between the Oligocene and the Miocene. This is a question which concerns areas outside that described in this memoir. The Upper Pegus or Miocene are poorly developed throughout the north of Minbu and the Pakokku district, and there are many local freshwater beds and many breaks in the series in the Upper Pegus of this area.

Origin of stage names.

Of the stage names given above, Akauktaung is from Henzada district, Kama and Pyalo from Thayetmyo district, Padaung and Shwezetaw from the Ngape section in south Minbu, and Singu from the Singu oilfield in Magwe district (sheet 84 L/13). Singu then is the only one of these names which derives from a locality in the map accompanying this memoir. The Padaung stage is, however, highly fossiliferous at Yenangyat, and Ngahlaingdwin.

Miocene poorly developed.

With the exception of a few fossils from the top Pegus near Myaung-u in the extreme south of sheet 84 L/6 and a few *Cyrenidæ* and *Melaniidæ* from other localities, the Miocene portion of the Pegus is poorly developed, and fossils, such as they are, are so poorly preserved as to be specifically unidentifiable as a rule; much of the Upper Pegus is of a freshwater or very shallow water marine type and is barren. There is no trace of the richly fossiliferous marine Miocene of Thayetmyo district.

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[1] World Petroleum Congress, Pre-Print No. 169, (1933).

In describing the Pegus of our area, we may first deal with the Pegus of the main western outcrop, and secondly with the Pegus of the Yenangyat, Singu, Pagan, and Gwegyo hills.

Pegus south of Ngahlaingdwin.

The country south of Ngahlaingdwin (sheet 84 L/6), and the Ngahlaingdwin sheet (84 L/5), was mapped by myself in 1909 and by Rao Bahadur Sethu Rama Rau in 1912. He states that the Pegus of these areas fall into two divisions, a lower consisting of sandstones with coal-seams, steel blue marine shales, and limestones, the shales and limestones being rich in fossils; and an upper, mainly of sandstones, grits and conglomerates, with subordinate shales of a shallow water type, and poor in fossils. The boundary between the two divisions is marked by a ferruginous gritty sandstone of unequal thickness, and there is probably some unconformity along this horizon. This ferruginous gritty sandstone passes into a ferruginous pebbly conglomerate with lenticles of coal. This bed was seen both in the monoclinally dipping Pegus south-west of Magyigon, a village not far from the Salin river, near the middle of sheet 84 L/6, and again in the Pegu syncline, between the Ngahlaingdwin anticline and the Nwanataung fold, near the village of Aleywa in sheet 84 L/5. The horizon is very easily traced in 84 L/6.

Median conglomerate.

S. R. Rau's work thus shows that the Pegus fall into two divisions separated by a probable unconformity, which would agree with the unconformity postulated by Mr. G. W. Lepper between the Oligocene and Miocene portions of the series. Unfortunately the beds above this line are very poor in fossils. Nevertheless, E. Vredenburg has recorded from the collections of S. R. Rau the following species near the top of the Pegus near Myaung-u in sheet 84 L/6:—

Pyalo stage.

Turritella pinfoldi, Vred.
Terebra myaunguensis, Vred.
Terebra promensis, Vred.
Ostræa latimarginata, Vred.[1]

Vredenburg points out that this indicates the Pyale stage.

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[1] See *Rec. Geol. Surv. Ind.*, LI, pp. 329, 348, 349, (1920).

Padaung stage of Myaung-u.

In the Padaung clay beds near Myaung-u, the following species were identified from S. R. Rau's collections by E. Vredenburg:—

Clavilithes seminudus (Noetl.).

Marginella orientalis, Vred.

Athleta jacobsi, Vred.

Melongena acanthina (Dalton).

Below these fossiliferous clays come the Shwezetaw sandstones which S. R. Rau calls 'sandstones with coal seams'; these are here barren of fossils.

Shwezetaw stage.

One mile west of Kyauk-o in the centre of sheet 84 L/6, I found the following fossils in the Shwezetaw sandstones in 1909:—

Purpura sp.

Lucina sp.

Ostræa sp.

Vicarya sp. cf. *verneuili*, D'Arch.

The last species also occurs in the Shwezetaw sandstones of the type area near Ngape.

In my survey of sheet L/6, I estimated the total thickness of the Pegus as upwards of 14,000 feet. The upper shallow water division of probable Miocene age was 5,500 feet thick between Magyigon and Kyauk-o.

Miocene beds near Ngahlaingdwin.

West of Kayingyauk village, I found two fossil beds (150 feet apart vertically) in the upper Pegus. In the upper bed were specimens of *Cyrena* (*Batissa*) *birmanica*, Vred. accompanied by specifically unidentifiable specimens of *Arca*, *Turcica*, *Paracyathus*. In the lower bed, *Batissa birmanica* again occurred with *B. kodaungensis*, Noetl. Another bed 1½ miles west of Magyigon contained *Batissa birmanica*, Vred and *Pecten* (*Chlamys*) *articulatus*, Sow. The age of these beds is probably Kama or Pyalo stage.

The upper Pegus in this area are charged with laminæ of selenite. The sandstones are very soft, of a blue-grey colour in fresh stream sections, alternating with light blue shales often stained with ochre. The sandstones are frequently current-bedded, and sometimes show ripple marks.

Singu stage of Ngahlaingdwin area.

The lower Pegus consist of about 5,000 feet of alternate sandstones and shales of Singu age; below these there are about 1,000 to 1,500 feet of Padaung clays, and below these are about 3,500 feet of Shwezetaw sandstone.

The Singu stage here consists of alternate beds of sandstone and shale with occasional bands of clay ironstone and conglomerate. Near the top of the stage *Turritella angulata*, Sow. occurs. This common Gaj form is also found in Singu. Near the base, at Ngahlaingdwin village, the following species were found :—

Nucula alcocki, Noetl.
Tellina protocandida, Noetl.
Cardita visquesneli, D'Arch. & Haime, *sec.* Noetling (*non C. visquesneli*, D'A. & H., which is a Laki species).
Corbula prototruncata, Noetl.
Tivela protphilipinarum, Noetl.
Hindsia birmanica, Vred.
Sigaretus nereitoides, Linn., *sec.* Noetl.
Athleta jacobsi, Vred.
Olivella minbuensis, Vred.

The *Cardita* figured by Noetling as *C. visquesneli* is quite different from D'Archiac and Haime's species, as L. R. Cox has pointed out (*op. cit.*, p. 70). It may perhaps be known as *C. noetlingi*.

Noetling's work on the lamellibranchs is in need of revision, but it has been thought advisable to give his determinations, except where they have already been corrected in published work.

Padaung stage of Ngahlaingdwin.

In the Padaung clay in the Tayu stream close to Ngahlaingdwin village, the following fossils were found :—

Nucula alcocki, Noetl.
Tellina protocandida, Noetl.
Tellina indifferens, Noetl.
Tivela protphillipinarum, Noetl.
Genotia iravadica, Noetl.
Cypræa (Bernayia) subexcisa, Braun.
Clavilithes seminudus (Noetl.)
Clavilithes arakanensis, Vred.
Hindsia pardalis (Noetl.)
Sigaretus nereitoides, Linn., *sec.* Noetl.
Athleta theobaldi, Vred.

Lyria varicosa, Vred.
Melongena præparadisiaca, Vred.
Tritonidea martiniana (Noetl.) var. *arakanensis*, Vred.

Shwezetaw stage.

At the base of the Shwezetaw sandstone north of Ngahlaingdwin, near the oil seepage, *Heterostegina* sp. was found, otherwise the sandstone appeared to be barren.

In the chapter on the Yaw stage, details of a section in the Salin river through the Pegus has already been given, (*see* pages 61-65). In this section, beds 16 to 20 are Miocene, beds 13 to 15 Singu stage, bed 12 Padaung clay, beds 9 to 11 Shwezetaw sandstones.

Yaw stage north of Ngahlaingdwin.

Sheet 84 L/5 and the northern part of 84 L/6, and 84 K/8 were mapped by H. S. Bion. Bion found that the Yaw stage was a well marked and easily recognised horizon, with *Velates* at the top. Above these, the Shwezetaw sandstones, which are 3,500 to 4,000 feet thick are nearly always barren. He describes them as well bedded massive sandstones with subordinate shale layers.

Above these the Padaung clay is a well marked band of clays, 100 to 1,500 feet thick, with abundant fossils, amongst which he recognised *Tellina protocandida*, Noetl. *Hindsia pardalis* (Noetl.), *Nautilus* sp., *Lucina globulosa*, Desh.

Above the Padaung horizon, the Singu stage and the Miocene together are 12,000 feet thick in the south of sheet 84 L/6, and are overlain by Irrawaddy sandstones without any noticeable break, conglomerates being rare.

Pegus decrease in thickness northwards.

Bion attempted to map certain shale horizons in the Pegus above the Padaung horizon, but he found this imposssible. He found that, on working north, the thickness of the Pegus steadily decreased, so that in the northern part of sheet 84 L/5, they were only 7,000 feet from the base of the Singu stage upwards. Moreover, the shales, so abundant in the south, were found to change rapidly to sandstones or quartz pebble conglomerates with abundant silicified fossil wood.

Change in facies of Pegus, north of Ngahlaingdwin.

In the section in the Thayetkon stream in the north of sheet 84 L/5, the Pegus on the eastern flank of the anticline, except in their lowest beds, are absolutely different from the Pegus of the south of sheet 84 L/6, and are lithologically identical with the Irrawaddy sandstones. It is evident, remarks Bion, that in the north we reach an old Upper Pegu land area, near which Irrawaddian conditions were established in Pegu times.

H. S. Bion gives the following comparative sections :—

I. Section about Lat. 20° 30′.	II. Section about Lat. 20° 57′.
Basal Irrawaddy conglomerate, 0 to 20 feet.	Basal Irrawaddy conglomerate.
Sandstones with a few ferruginous pebbly layers, 5,000 feet.	Conglomerate and gravel, 2,000 feet.
Alternations of blue shale and sandstones, 2,500 feet.	Massive white sand-rock, 3,000 feet.
Sandstone, 2,000 feet	Thin bedded sandstones with subordinate shales, 1,500 feet.
Blue shales and sandstones, 1,500 feet	
Sandstones, 500 feet	
Padaung clay	Padaung clay.

The three comparative sections given on page 82 illustrate the thinning down and lateral change of the Pegus. The first section is in the southern part of sheet 84 L/6 near the line of the Thabyebin stream; the second, a section through the Zaha stream near the south margin of 84 L/5, and the third is along the Thayetkon stream in the north of 84 L/5.

Irrawaddy beds unconformable to Pegus.

Bion regards the Pegu-Irrawaddy boundary as unconformable. This unconformity, he says, is very small in the south but increases northwards owing to the regression of the Irrawaddy series. In the Pegus themselves he does not recognise any unconformity in the southern section, but says that there are many breaks in the sequence of the Pegus towards the north.

Padaung clays disappear in 84 K/8.

Finally in sheet 84 K/8, the Padaung clays themselves, which formed a constant and mappable belt in the country from the north of sheet 84 L/5 to the Ngape section in south Minbu, fail owing to the steady change of facies of the Pegus. The Padaung clays cannot be traced further north than lat. 21° 5′. Between lat. 21° 0′ and 21° 5′ they are traced with some difficulty, but to the north they pass laterally into sandstones inseparable from the Pegus

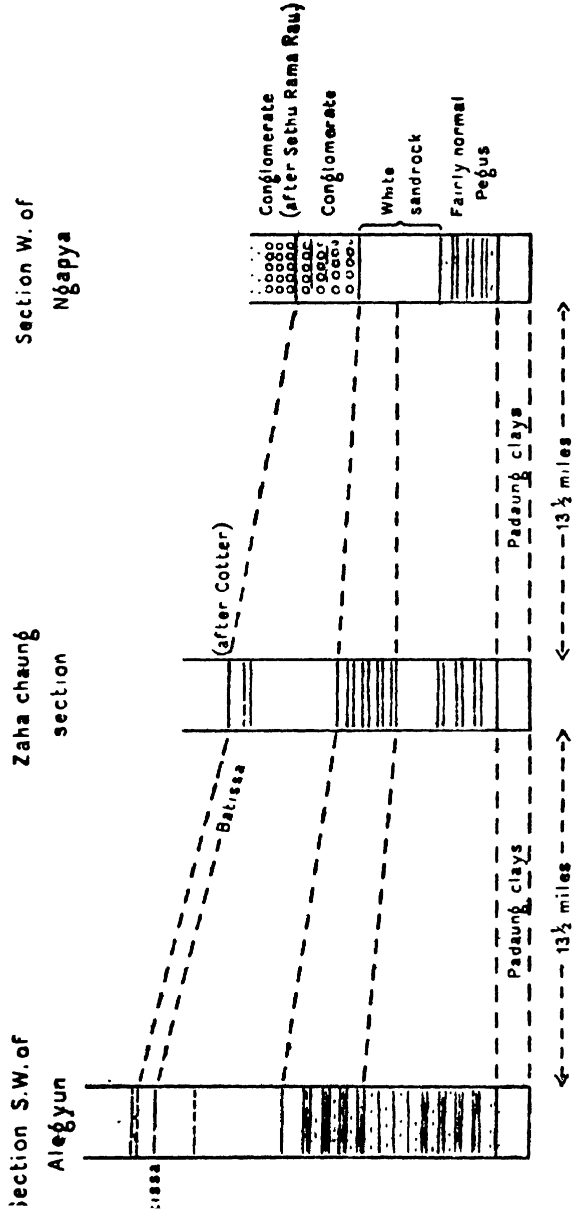

FIG. 2.—Sections illustrating lateral change in the Pegus.

above and below. North of this latitude too, the *Velates* bed, which had been taken as the top bed of the Yaws, is no longer found, since it is replaced by sandstones. There is thus a transgression of the lithological lines over the faunal lines, the base of the Shwezetaw stage in Pakokku containing some strata of sandstone which are the same horizon as the *Velates* bed in the Minbu district, while the Yaw stage in Pakokku excludes the *Velates* zone. For practical mapping purposes it has been necessary to keep to the lithological lines, the main Yaw shales being continuous throughout. North of lat. 21° 5′, the Pegus are mainly a freshwater formation, and Yaw stage marks the latest marine phase.

Stratigraphical position of Velates bed.

The Pegus of sheet 84 K/7, which were mapped by myself, are current-bedded sandstones and conglomerates from top to bottom, the Padaung clays being represented by sandstone, and the whole series showing no lines of demarcation, whereby it can be subdivided. There is however from about the middle of the sheet northwards a bed of red conglomerate which divides the series into two portion of about equal thickness. This bed can be traced throughout the sheet to the north (84 K/6), but in the extreme north of this sheet it thins and dies out. I formed the conclusion that this bed came a little way above the horizon of the Padaung stage. It has been previously shown that Rao Bahadur S. R. Rau's survey of sheet 84 L/6 disclosed the presence of a similar bed of red ferruginous conglomerate and grit above the Padaung clay and Singu stages; it is possible that the two beds may correspond, but perhaps the safer attitude is to say that in the absence of fossil evidence, we cannot correlate the two beds with certainty.

Coastal and fresh-water Pegus of west Pakokku.

Median red bed.

Above this median red bed, the Pegus of 84 K/7 and K/6 are current-bedded sandstones with fossil wood, very like the Irrawaddy sandstones above, especially in sheet 84 K/6.

Only in one place were fossils found; this was 2¼ miles north-west of Nyaungbintha close to the Tilin road in south-east quadrant of 84 K/6, where specimens of *Batissa crawfurdi*, Noetl. were found.

In sheet 84 K/7, the total thickness of the Pegus is about 6,600 feet. The series grades from estuarine beds below to fluviatile above. The median red bed which subdivides the series is about 3,400 feet below the base of the Irrawaddy series. Above this horizon,

Thickness of fresh-water Pegus of west Pakokku.

the beds are entirely fluviatile, current-bedded, poorly stratified. with fossil wood, and are not easily distinguishable from the Irrawaddy beds. The latter however have a gleaming white appearance in cliff sections, and are a looser, softer sand-rock formation. The upper Pegus are light cream-colour; the bedding-lines are on the whole more definite; there are frequent cannon-ball concretions.

Shallow marine lower Pegus.

Below the median red conglomerate, there are about 1,300 feet of beds mainly sandy, but which show more definite bedding, and which contain in a few places some poorly preserved fossils. A fossil-bed lying close to the thirteenth milestone on the Pauk-Pasok road yielded the following species:—

Meretrix (*Tivela*) *protophilippinarum*, Noetl.
Calliostoma sp.

A cast, possibly of *Tritonidea martiniana*, Noetl., was also found. This zone of beds with occasional marine fossils can also be traced in sheet 84 K/6. In the north of that sheet some specimens of a coral resembling *Dendrophyllia digitalis*, Blainville. It is very possible that part of this zone of shallow water beds with traces of marine fossils may represent the Padaung stage.

Coal-seams in Shwezetaw stage.

Underneath this zone of beds with occasional marine fossils come the equivalents of the Shwezetaw sandstone. These beds are, in sheet 84 K/7, characterised by coal-seams, and by abundant fossil wood immediately above and below the coal-seams. The coal is developed mainly in the country south of the Yaw river, and has not been found east of the Pondaung range in the area north of the Yaw. It is of course possible that the seams may be invisible and covered by surface soil. The belt of fossil wood near the base of the Pegus can however be traced throughout 84 K/7 and K/6.

Gypsum is of common occurrence both near the coal-seams and near the horizon of the median red bed. It can also be seen at the base of the Pegus west of Man village near mile 23 on the Pauk-Pasok road.

One furlong east of Tazu in the south of the same sheet specimens of *Cyrena borneensis*, Bottger were found. The same species was also found about 3 miles S. S. E. of Tazu near the coal-seams, and a fragment of the same species about ¼ mile south of Myeni (mile 14 on Pauk-Pasok road).

Upper Pegus no longer separable from Irrawaddy beds in north-west Pakokku.

In the north of sheet 84 K/6, and in the country south of Letpan (21° 49′: 94° 30′), there is great difficulty in drawing a boundary between the Upper Pegus and the Irrawaddy beds. In the country to the south the boundary is marked by red earth beds, red gravel beds or red conglomerates. But in sheet 84 K/6 other red beds make their appearance in the Upper Pegus, and the Upper Pegus themselves are no longer distinguishable from the Irrawaddy beds; the boundary has been drawn by walking along the strike, but it no longer represents a recognisable mappable field horizon

Pegus of Kyaw valley.

The Pegus of 84 K/5 were mapped by Capt. F. W. Walker, as well as the Pegus of 84 J/8 and J/12. I take the following description from his progress report. Near the base, the Shwezetaw stage seems to be present in K/5, and the Pegus of J/8 and 12 are also mainly Shwezetaw. The predominant rock is a 'pepper and salt' sandstone, soft and friable, and of a fine grain. Higher in the series clay and shale bands of a light blue colour appear, and sometimes attain a thickness of 20 feet. These bands are not however constant, but pass laterally into sandstones. In the south-west of sheet 84 K/5, the rock is a friable white sandstone resembling the Irrawaddy beds.

In the outlier of Pegus in 84 J/12, the Khodaung hill is covered by a quartz pebble conglomerate.

In sheet 84 K/5, about one mile east of Tandaw, a belt of shale was found containing strings of coal, and some fossils. Amongst which were a *Voluta* resembling *Athleta jacobsi*, Vred. and unidentified species of *Dolium*, *Conus*, *Pleurotoma*, *Oliva*, and *Ampullina*. Near this locality, another collection was made from a spot five furlongs north-east of Zaho, from which *Natica* sp., and *Trochus* sp. were obtained.

Fossil wood is in this area abundant in the Pegus, and is sometimes silicified, sometimes carbonised. Logs up to 25 feet in length and up to 3 feet diameter were found in the Kyetyin stream south of Letpan (south-east corner of K/5).

Three sub-divisions of Pegus north-west of Myaing.

In sheet 84 K/10, the Pegus fall into three subdivisions roughly. The upper beds are current-bedded sandstones with fossil wood; the middle division is composed of alternations of shale and sandstone, with occasional beds of broken fossils. The lower division is of coarse sandstone with fossil wood. Roughly, these three divisions may correspond with Upper Pegus, the Padaungs, and the Shwezetaw sandstones. But it cannot be determined whether the Singu stage comes in the upper part of the middle division or the basal beds of the upper, since the fossils are unidentifiable.

In sheet 84 K/14 the Pegus become earthy and fluviatile deposits, and, although they simulate the Irrawaddy beds, I formed the opinion when mapping this area that the Irrawaddy beds overlap the Pegus, whilst the Pegus themselves are thinning down; thus near Myaing the Pegus are almost entirely overlapped, and the Irrawaddy beds rest on about 1,000 feet of fluviatile beds which may be Pegu or older, and these in turn on the Yaw stage at Myaing and along the Myaing anticline to the south.

CHAPTER X.

THE PEGUS OF THE YENANGYAT AND SINGU OILFIELDS, AND OF THE PAGAN AND GWEGYO HILLS.

It will be advisable to commence the description of the Pegus of the oilfields with the Singu exposures.

The Singu anticline lies in sheet 84 L/13, and is bounded on the north-west by the Irrawaddy river. On the other side of the river, the anticline continues in a N. N. W. direction for about thirty miles, but it is known as the Yenangyat field. The fold is asymmetric, being steeper on the eastern flank; this contrasts with the Ngahlaindgdwin fold which has a steeper western limb.

Thickness of Pegus at Singu oilfield.

Owing to the development of a fold-fault in the eastern flank of the anticline, the upper Pegus are cut out on the eastern side of the anticlinal crest. Sir E. H. Pascoe[1] gives a thickness of 1,450 feet of Pegu beds east of the crest in the latitude of Chaukywa, and the thickness of the Pegus west of the crest is probably 2,400 feet according to Rao Bahadur S. R. Rau[2], or 2,450 feet according to G. E. Grimes. The difference in thickness is thus about 950 to 1,000 feet.

Mr. S. R. Rau's work.

In the map accompanying Mr. Rau's paper, the various fossil beds are traced on either limb, and it is evident that the missing beds are the uppermost Pegus. Mr. Rau regards the uppermost 900 feet as the equivalents of part of the Kama stage, that is, its lower portion. The beds are alternates of sandstone, shale, and impure limestone. These beds have only a few poorly preserved fossils. At the top of the formation is a bed known as the '*White Sand*'.

G. E. Grimes[3] thus describes the White Sand :—

White sand.

> 'The uppermost bed of the upper miocene is, when present, quite distinct from the beds below, and it can be easily identified, especially as its colour is so conspicuous, that it can often be distinguished at a considerable distance off .... It usually contains

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[1] Sir E. H. Pascoe, Oilfields of Burma, *Mem. Geol. Surv. Ind.*, XL, Pt. 1, p 110, (1912).

[2] Rao Bhdr. S. R. Rau, Stratigraphy of Singu-Yenangyat Area, *Rec. Geol. Surv. Ind.*, LIII, p. 321, (1922).

[3] *Mem. Geol. Surv. Ind.*, XXVIII, p. 40, (1900).

pieces of gypsum, and in a few places fragments of wood partly replaced by oxide of iron, etc., these last are very friable .... This upper sand is of very variable thickness; it is exposed all along the western miocene boundary of the Singu Yenangyat anticline, but, with the exception of a small length at the southern end, it is not present on the eastern side.'

Mr. Rau states that the White Sand in the Singu field is 10 to 50 feet thick, and that there are many ferruginous beds intercalated with it grading from brick-red sandstone to lateritic conglomerate.

Above the White Sand lies the basal bed of the Irrawaddy series, the Ferruginous Conglomerate or Ferruginous Earth bed. These two strata are constant all along the western flank of the Singu-Yenangyat fold.

Below the Kama stage at Singu there are exposed about 1,500 feet of highly fossiliferous beds, in which Mr. Rau traced ten fossil beds. These are alternations of well-bedded sandstone and blue shale with marl or limestone bands.

Singu stage.

E. Vredenburg has made a careful analysis of the fauna[1] of these beds, and concluded that it was Oligocene, and probably of Chattian age, and that all the ten fossil beds constituted a single stage which he named the 'Singu stage'. The assemblage of fossils is very similar to those collected by myself from the beds immediately above the Padaung clay in the Ngape section. Vredenburg showed that the Singu stage comes immediately above the Padaung clay stage.

The following is a list of the fauna of the Singu stage : —

Echinoidea :—

Thylechinus sethuramæ, Vred.

Corals :—

Dendrophyllia digitalis, Blainville.
Dendrophyllia macroriana, Pascoe & Cotter.
***_Paracyathus_ sp. cf. _tasmanicus_.
*_Eupsammia_ sp. (non _Eupsammia regalis_, Alcock).

Lamellibranchiata :—

Lima protosquamosa, Noetl.
*_Chlamys irravadicus_, Noetl.
Pteria suessiana, Noetl.
**_Vulsella lingua-tigris_, Noetl.
Septifer nicobaricus, Reeve.

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[1] _Rec. Geol. Surv. Ind._, LIII, p. 331, (1922).

Modiola buddhaica, Noetl.
Lithophaga sp.
*_Arca bistrigata_, Dunker.
***_Nucula alcocki_, Noetl.
Nuculana (?) birmanica, Noetl.
Cardita scabrosa, Noetl.
Cardita (Arcinella) tjidamarensis, Martin.
**_Venericardia noetlingi_, nom. nov.[1]
Crassatella dieneri, Noetl.
**_Cardium (Trachycardium) minbuense_, Noetl.
Meiocardia metavulgaris, Noetl.
Antigona granosa (Sow.)
**_Pitar protolilacina_, Noetl.
***_Pitar amygdaloides_, Noetl.
***_Tivela protophilippinarum_, Noetl.
**_Apolymetis grimesi_, Noetl.
*_Gari kingi_, Noetl.
Gari deuterokingi. Noetl.
Corbula rugosa, Sow.
Scaphopoda :
**_Dentalium junghuhni_, Martin.
Gastropoda : -
***_Architectonica maxima_, Philippi.
Calliostoma singuense, Vred.
**_Basilissa loriolana_, Noetl.
**_Turcica protomonilifera_, Noetl.
*_Calyptraea rugosa_, Noetl.
***_Natica obscura_, Sow.
***_Sigaretus neritoides_, Linne.
**_Turritella angulata_, Sow.
*_Turritella magnsperula_, Sacco.
Vicarya verneuili, D'Archiac.
*_Cassis birmanica_, Vred.
**_Galeodea echinophora_, Linn.
*_Ficus conditus_, Brongn. var _singuensis_, Vred.

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[1] This species is identified by F. Noetling, [_Pal. Ind._, N. S., Vol. I, Pt. 3, p. 167, Pl. IX, figs. 6 & 7, (1901)] as _Cardita viquesneli_, D'Archiac & Haime. D'Archiac and Haime's species is, however, from the Laki stage of India, and it has been pointed out by L. R. Cox [_Trans. Roy. Soc. Edin._, LVII, Pt. I, (No. 2), p. 70, (1931)], that the Burmese species is quite different. Noetling's species may therefore be known as _C. noetlingi_. Noetling has (p. 170) described another species as _Cardita_ cf. _C. mutabilis_, D'A. & H. This again is from the Ghazij shale and is also recorded from the Ranikot beds.

Cypraea (*Cypraeotrivia*) *oppenheimi*, Vred.
Cypraea (*Bernayia*) *singuensis*, Vred.
***Distorsio reticulata*, Linn. var. *subelathrata*, D'Orb.
**Tritonidea martiniana* (Noetl.)
Thais singuensis, Vred.
****Clavilithes seminudus*, Noetl.
Vasum basilicum, Bellardi.
****Melongena praeponderosa*, Vred.
Melongena pseudobucephala Noetl.
Melongena acanthina (Dalton).
**Athleta jacobsi*, Vred.
**Lacinia minbuensis*, Vred.
Mitra singuensis, Vred.
Marginella singuensis, Vred.
****Olivancillaria nebulosa*, Lmk. var *pupa*, Sow.
Ancilla (*Sparella*) *birmanica*, Vred.
Turris singuensis, Vred.
Clavatula (*Perrona*) *birmanica*, Vred. var. *singuensis*, Vred.
**Clavatula protonodifera*, Noetl.
**Genotia irravadica*, Noetl.
Genotia singuensis, Vred.
****Conus odengensis*, Martin var. *avaensis*, Noetl.
**Conus ineditus*, Michelotti.
**Terebra quettensis*, Vred.
**Surcula feddeni*, Noetl.
Arthropoda :—
****Balanus* (*Chirona*) *birmanicus*, Withers.
****Calianassa birmanica*, Noetl.

In the foregoing list the species marked with one asterisk are found in the beds below (Yenangyat or Minbu), those marked with two asterisks in the beds above (Kama), and three asterisks mean that the species ranges both into the stage below and that above.

Relationships of Singu fauna.

Fifteen species are found in the stage below, and not in the stage above; nine species in the stage above and not in the stage below, and thirteen species range both above and below.

Vredenburg regards the fauna as Chattian (or late Oligocene). Generally his reasons are as follows :—

(1) There is a very close relationship with the Yenangyat or Padaung fauna; the relationship to the Kama stage is more distant.

(2) There are several distinctly Oligocene species. *Vasum basilicum* and *Turritella magnasperula* are from the Oligocene of Europe. *Terebra quettensis* and *Conus ineditus* are found in the Nari of India. On the other hand there are several Miocene elements; thus several species range up into the Kama stage; some (*Conus odengensis*, *Vicarya verneuili*, *Turritella angulata*, *Olivancillaria nebulosa* var. *pupa*) occur also in the Gaj of India.

Cypraea singuensis is very close to *C. humerosa*, Sow. which is a typical Gaj form; on the other hand *Thylechinus* is found in the Nari of Baluchistan.

Singu fossil beds in south Yenangyat.

It has been mentioned above that Mr. S. R. Rau traced ten fossil beds in the Singu field. He succeeded in tracing three of these beds into the Yenangyat anticline across the Irrawaddy river. These beds were (1) the lowest bed, which is exposed on the crest at Singu; this is known as the *Dendrophyllia* bed, and this bed is easily recognised by its assemblage of fossils. *Dendrophyllia macroriana*, *D. digitalis*, *Antigona granosa*, *Nucula*, *Cypraea*.. (2) the '*Pyrula*' bed with *Melongena* and *Vicarya*, and (3) the *Mytilus* (*Septifer*) *nicobaricus* bed, which is the uppermost of the beds mapped in Singu.

The *Dendrophyllia* bed was traced for about two miles west of the anticlinal crest in the country west of Kyauksaung, a village five miles south of Yenangyat. In Singu its stratigraphical distance above the crest was 300 feet. Near Kyauksaung, the distance was 1,270 feet. This indicates that the crest has risen between Singu and Kyauksaung by nearly 1,000 feet.

Rise in the anticlinal crest of Yenangyat fold.

According to Sir E. H. Pascoe[1], there is a rise in the crest to the north between Block 17 south of Kyauksaung and Yenangyat village. This works out from his sections at 1,700 feet. Assuming that at Kyauksaung itself the crestal beds are say, 200 feet lower than in Block 17 (*i.e.*, that the crest has risen by 200 feet) then the difference in stratigraphical horizon of the crest at Yenangyat and at Kyauksaung would be 1,500 feet and the difference between Singu and Yenangyat village area would be 2,770 feet.

It is clear then from Mr. Rau's work that the crestal beds of Yenangyat are very much older than those of the Singu field, and it is not surprising that they should turn out to belong to an older stage, *viz.*, the Padaung stage.

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[1] *Op. cit.*, Pl. XXXI.

Mr. Rau's work extended only to the southern part of the Yenangyat field. In this southern part, the following fossils were collected from the Red Conglomerate that lies on the Irrawaddy—Pegu boundary on the west margin of the anticline :—

Taia (*Rivularoides*) *spinifera*, Annandale.
Batissa sethuramae, Vred.

But although Mr. Rau was able to trace some of the Singu fossil beds into southern Yenangyat, the facies of the Singu stage was seen to be gradually changing, and the stage was becoming more and more of an estuarine character. This accounts for the fact that near Kyauksaung only three out of the ten beds could be traced, while, in the latitude of Yenangyat, these three fossil beds can no longer be traced. The bands of fossiliferous marls and limestones are replaced by shale and sandstone.

Geological maps of the Yenangyat oilfield have been published by G. E. Grimes[1], Sir E. H. Pascoe,[2] and for the northern part by myself[3], and in the memoirs and paper accompanying these maps, descriptions of the strata are given. The Singu stage, which Mr. Rau showed was changing laterally into a more estuarine type of beds as one travels north towards Yenangyat, becomes fully estuarine in the northern section mapped by myself. Here the Kama and Singu stages together are about 2,000 feet ; the uppermost 300-400 feet are fluviatile with red beds and much fossil wood ; below these beds are 1,600 feet of strata consisting of current-bedded sandstones, pale silty shales, some red earth, some fossil wood, and a few bands of badly preserved fossils, amongst which were *Balanus birmanicus*, a large *Ostraea*, and bones of crocodile.

Change in facies of Singu stage.

Beneath the Singu stage comes a series of well bedded sandstones and shales, with limestone and marly bands and well preserved fossils. These beds are, in fact, very like the Singu stage at Singu, although they are in reality older. It may be remarked that lithological resemblances between successions and strata of different ages are common in Burma. Thus the Yaw river section, where the whole of the Pegus rest upon the Yaw stage, is very like the Ngahlaingdwin section, where the Upper Pegus and Singu stage rest upon the Padaung clay. Without an examination of the fossils and a knowledge of their ranges, it would be easy to conclude that the Padaung clay at Ngahlaingdwin is to be correlated with the Yaw shale. But we now know that the former is Oligocene, the latter Eocene.

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[1] Geology of parts of Myingyan, Magwe, and Pakokku Districts, by G. E. Grimes, *Mem. Geol. Surv. Ind.*, XXVIII, p. 30, and Pl. II, (1900).

[2] Oilfields of Burma, by Sir E. H. Pascoe, *op. cit.*, XL, Pl. 29, (1912).

[3] Northern Part of Yenangyat Oilfield, by G. de P. Cotter, *Rec. Geol. Surv. Ind.*, XXXVIII, p. 302, and Pl. 28, (1910).

Deceptive similarity of sections of different age.

Thus F. Noetling regarded the fossiliferous sandstones and shales of Yenangyat and of Singu as of approximately the same age. His fossil zones were founded to some extent upon these false lithological analogies; his lowest zone called 'zone of *Anoplotherium birmanicum*' applies to beds at Yenangyaung which are most probably well above the Singu stage; he places the main fossil bed of Minbu below that of Yenangyat, and he regards the whole of the fauna as Miocene. Nevertheless that of Kama is clearly Miocene, that of Singu is probably uppermost Oligocene, and that of Minbu and Yenangyat are Oligocene, Yenangyat being the oldest. This sequence has been clearly proved by E. Vredenburg.

It is remarkable also that only thirteen miles in a north-easterly direction from the northern termination of the Yenangyat anticlinal inlier of Pegu rocks, we find in the Myaing fold an utterly different sequence. There the Pegus are almost entirely cut out by the overlap of the Irrawaddy sandstone, which rests, with only 1,600 feet of fluviatile beds intervening, upon the Yaw stage. Yet in Yenangyat there are 3,740 feet of Pegu beds exposed, where the crest is at its highest, below the Irrawaddy beds, and the Yaw stage is nowhere exposed.

Attenuation of Singu and Kama stages at Yenangyat.

If the thickness of beds at Singu above the *Dendrophyllia* bed is 2,150 feet, as Mr. Rau calculates, it might be rashly assumed that of the 3,740 of beds exposed west of Yenangyat, only 1,590 feet of beds, the lowest exposed, are older than the *Dendrophyllia* horizon. That such a figure is too small is shown by the calculations quoted above from Mr. Rau's paper,* from which it is deduced that the crestal beds at Yenangyat are 2,770 feet lower than the crestal beds at Singu, where the *Dendrophyllia* bed is found about 300 feet above the crest. The thickness of 3,740 feet is that given by Sir E. H. Pascoe in his memoir on the oilfields of Burma p. 110. It is desirable that this figure should be rechecked, as it seems low for so wide an outcrop. The *Dendrophyllia* bed cannot be traced in the strata of the upper Pegus west of Yenangyat, because of the change of facies, but it is to be assumed that the beds from the Singu stage upwards are considerably thinner than at Singu. This explains why the Yenangyat stage is more than 1,590 feet thick.

Mr. Rau's comparative sections.

Mr. Rau, on Plate 20 of the volume of the *Records* in which his paper appeared, has given comparative sections of the Singu and Yenangyat fields. These sections are reproduced on Plate 11. It will be seen that, if Mr. Rau's section is measured, taking the scale as 1 inch=1,000 feet the thickness of Pegu beds above the crest works out at 4,800 feet. Yet the true thickness is 3,740 feet[1] according to Sir E. H. Pascoe.[1] This, if correct, means that there has been a thinning down of strata as one travels northwards, amounting to 1,060 feet. It may reasonably be assumed that this thinning is a concomitant feature of the change of facies of the Singu stage and the beds above from marine to estuarine.[2]

Mr. Rau has drawn the sections side by side so as to bring the same beds in each section horizontally opposite. It would have been impossible to draw the actual thickness, because the Singu fossil beds are not found in the latitude of Yenangyat, but die out about 5½ miles to the south. It is impossible to estimate at what horizons the thinnings out have occurred. Nevertheless it seems wise to point out that such thinning *does* occur, and that it affects in all probability the estuarine strata.

Fauna of Yenangyat or Padaung stage.

It has been mentioned above that the fauna of Yenangyat is older than that of either Minbu or of Singu, and that it is correlated with the Padaung stage by E. Vredenburg. The following is a list of the species identified:—

**Pecten* (*Chlamys*) *irravadicus*, Noetl.

Corals:

***Paracyathus* sp. cf. *tasmanicus*.

**Eupsammia* (*Balanophyllia*) sp.

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[1] *Op. cit.*, p. 110.

[2] *Note.*—The difference in thickness of the Pegus east and west of the crest in the Singu-Yenangyat fold will be dealt with in the chapter on structure.

Lamellibranchiata :
*_Pecten (Chlamys) irravadicus_, Noetl.
*_Arca bistrigata_, Dunker.
*_Nucula alcocki_, Noetl.
**_Lucina pagana_, Noetl.
Lucina d'Archiaciana, Noetl.
*_Pitar amygdaloides_, Noetl.
Tivela dubiosa, Noetl.
**_Tivela protophilippinarum_, Noetl.
Tellina hilli, Noetl.
**_Gari kingi_, Noetl.
*_Bicorbula prototruncata_, Noetl.
Gastropoda :
*_Architectonica maxima_, Philippi.
Calliostoma blanfordi, Noetl.
Torinia buddha, Noetl.
Clathrus leptopleuratus, Noetl.
**_Natica callosa_, Sow.
**_Natica obscura_, Sow.
**_Sigaretus neritoides_, Linne.
*_Turritella magnsperula_, Sacco.
*_Calyptraea rugosa_, Noetl.
Ficus conditus, Brongn.
*_Cypraea (Cypraeotrivia) oppenheimi_, Vred.
Trivia noetlingi, Vred.
Hindsia neastriatula (Noetl.)
**_Hindsia pardalis_ (Noetl.)
Ranella tubercularis (Noetl.) (=_Ranella prototubercularis_ Noetl.)
**_Clavilithes seminudus_, Noetl.
Lathyrus indicus, Vred.
*_Tritonidea martiniana_ (Noetl.)
Murex (Muricantha) iravadicus, Vred.
Murex iravadicus var. _yenanensis_, Vred.
*_Athleta (Volutospina) jacobsi_, Vred.
*_Melongena acanthina_ (Dalton).
*_Athleta jacobsi_, Vred. var. _singuensis_, Vred.
Olivella minbuensis, Vred.
Morica pseudocanellata (Noetl.)
Hindsia birmanica, Vred.
*_Surcula feddeni_ (Noetl.)

**Terebra quettensis*, Vred.
Turris (Hemipleurotoma) yenanensis, Noetl.
**Conus inoditus*, Mich.
Conus protofurvus, Noetl.
Conus (Conospira) galensis, Noetl.

Arthropoda:
***Balanus (Chirona) birmanicus*, Withers.

In the above list, the species marked (*) occur in the Singu fauna, and those marked (**) occur in the stage above (Kama). Of the forty-six species listed, nineteen do not occur in the Singu or Kama stages. Only ten species range as far as the Kama stage. This fauna is correlated with the Padaung fauna of south Minbu by E. Vredenburg. In this type area of the Padaung clay *Tritonidea martiniana*, *Conus protofurvus* and other species of gastropods are found in conjunction with *Lepidocyclina theobaldi*, Carter and a *Schizaster* allied to *S. baluchistanensis*, D'Arch.

Correlation with Padaung fauna of south Minbu.

The correlation is based not only upon the similarity of the faunas, but upon the stratigraphical position, since the Singu fauna is found in the alternates immediately above the Padaung stage. The Padaung stage was correlated by me with the Upper Nari of India, but E. Vredenburg has correlated the Singu stage with the Upper Nari, and places the Padaung stage immediately below. Vredenburg's conclusions are, however, based upon a very much more extensive collection of fossils than were mine. My original paper was published in 1912, while the first paper of Vredenburg upon this subject is dated 1920; in this interval a great amount of fieldwork had been done. I now accept the views of E. Vredenburg.

I have already mentioned that the topmost bed of the Pegus all along the western boundary in Singu and Yenangyat is the White Sand, and upon it the basal bed of the Irrawaddy series is known as the Ferruginous Conglomerate or Red Earth. The White Sand varies in thickness from 10 to 50 feet; its brilliant white colour is due to kaolin.

The eastern boundary will be discussed in the chapter upon the structure. In this memoir, I do not propose to repeat again what has been said about the Singu-Yenangyat field by G. E. Grimes and Sir E. H. Pascoe. The remarks made above are intended as supplementary to Sir E. H. Pascoe's description.

The Pagan and Gwegyo hills lie mainly in sheets 84 K/16 and 84 L/13. They have been described by G. E. Grimes in the paper previously quoted, and subsequently in two papers by Sir E. H. Pascoe, and myself.[1]

Pagan hills.

The Pagan hills commence about five miles south-east of Pagan and run for some fourteen miles in a S. S. E. direction. They form a landmark visible from great distances, since they rise suddenly and abruptly from a comparatively level alluvial plain. They are composed entirely of Pegu rocks, and consist mainly of rocks dipping W. S. W. at about 35.° In a very few sections a small thickness of steeply dipping Pegus are exposed on the east flank, and there is then an asymmetrical anticlinal fold. But over the main body of the hills the steeply dipping eastern limb has been destroyed by fold-faulting.

The upper beds of the Pegus here consist of alternations of sandstone and shale, but sandstone predominates. The thickness of the Pegus is between 2,000 and 2,500 feet (Grimes). The lowest beds exposed near the centre of the hills are shale of a deep blue colour, which contrasts with the greenish grey colour of the upper shales. As these hills are arranged in echelon with the Gwegyo hills to the south, it is to be assumed that they are the same strata of Pegus; if that is so, then it may be assumed that the upper beds are Singu stage, and the basal beds Yenangyat stage. The structure will be discussed in a later chapter.

Gwegyo hills.

The Gwegyo hills trend in the same S. S. E. direction as the Pagan hills, but are aligned in echelon to them, being nearer to the Yenangyat hills than are the Pagan hills. They rise from fairly level ground abruptly as do the Pagan hills, but there is less alluvium, and more exposures of Irrawaddy sandstone around them. To the S. S. E. there is a continuation of Pegu beds in more or less sunken relief; this is known as the Payagyigon-Ngashandaung field, (although it has been more or less a failure as an oilfield).

The Gwegyo hills themselves are about 14½ miles long; there is then an alluvial tract 2½ miles wide, and then the Pegu outcrop of the Gwegyo hills is continued to the S. S. E. as an area of sunken relief for seven and a half miles. In the map accompanying this paper only the northern part of the hills is shown, but it is necessary to treat the whole outcrop as a unit for descriptive purposes.

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[1] Sir E. H. Pascoe, The Northern Part of the Gwegyo Anticline, *Rec. Geol. Surv. Ind.*, XXXIV, p. 261, (1906).

G. de P. Cotter, Southern Part of the Gwegyo Hills, *op. cit.*, XXXVII, p. 225, (1909).

See also Sir E. H. Pascoe, Oilfields of Burma, *Mem. Geol. Surv. Ind.*, XL, (1912).

Unlike the Pagan hills, says Grimes, shales are here predominant, and the beds resemble those of Singu, but the uppermost White Sand bed is missing. There is much selenite and some calcite laminae in the shales.

Although shales predominate, there is a capping layer of hard sandstone, and the dip is W. S. W. at angles generally from 30° to 40°, or perhaps more. The anticline has been destroyed by fold-faulting, and only the westerly dipping limb remains; the steep easterly dipping limb has disappeared. In the Payagyigon-Ngashandaung field, the rarity of sandstone reinforcements has caused the shales to be excavated below the level of the surrounding country. There are traces of the anticlinal fold in the extreme north of the hills and also in the southern termination near Ngashandaung.

Tetma fauna.

No fossils have been collected from the Pagan hills by the Geological Survey of India. Near the village of Tetma, which lies at the northern extremity of the Gwegyo hills, a collection has been made, from which the following species were described by E. Vredenburg:—

Surcula birmanica, Vred.
Ancilla (*Sparella*) *indica*, Vred. var. *arakanensis*, Vred.
Athleta (*Volutospina*) *jacobsi*, Vred.
Turricula birmanica. Vred.
Fuscus buddhaicus, Vred.
Lathyrus sindiensis, Vred. var. *birmanica*, Vred.
Lathyrus indicus, Vred.
Melongena (*Pugilina*) *praeponderosa*, Vred.

This fauna is regarded by E. Vredenburg as of Padaung age.

Fauna of Gwegyo hills.

From a stream-bed about 2 miles S. S. W. of Kyauktan village in the Gwegyo hills, at a horizon high up in the Pegu strata of those hills, I obtained a collection, of which I have given the identifications in my paper above quoted. Amongst these were—

Tellina hilli, Noetl.
Tivela protophilippinarum, Noetl.
Turritella angulata, Sow.

Hindsia pardalis (Noetl.)
Hindsia birmanica, Vred.

The identifications have been revised in accordance with E. Vredenburg's revision of Noetling's work. Very possibly this fauna is of Singu age, but it is so scanty that we cannot be certain, and it may be as old as Padaung.

Padaung stage fauna of Payagyigon.

Good collections of fossils were made by myself from the northern end of the Payagyigon-Ngashandaung field to the south of the Gwegyo hills. Full lists of these are given in my paper above quoted. Further collections were made about three miles to the south. I shall not repeat again here the lists already published, but it is perhaps worthwhile to give a list of those species which E. Vredenburg in his papers upon Indian Tertiary Gastropoda (see *ante*) identified from Payagyigon. The list is as follows :—

Surcula (*Pleurofusia*) *feddeni*, Noetl.
Surcula (*Pleurofusia*) *fusus*, Vred.
Turris (*Hemipleurotoma*) *humilis*, Beyrich, var. *irawadica*, Vred.
Conus ineditus, Michelotti.
Athleta (*Volutospina*) *jacobsi*, Vred.
Turricula birmanica, Vred.
Fusus humei, Vred.
Lyria varicosa, Vred.
Euthriofusus alomprae, Vred.
Lathyrus sindiensis, Vred., var. *birmanica*, Vred.
Siphonalia cotteri, Vred.
Cyrtochetus minbuensis (Noetl.)
Tritonidea martiniana (Noetl.) var. *arakanensis*, Vred.

The fauna is clearly Oligocene. Vredenburg places it in the Padaung stage.

CHAPTER XI.

THE IRRAWADDY SERIES AND THE MAW GRAVELS.

The term 'Irrawaddy series' was first used by F. Noetling to denote the freshwater series which is found resting upon the Pegu beds in upper Burma, and especially in the type area of Yenangyaung.[1] It has been explained in Chapter IX that this term is not quite synonymous with W. Theobald's term 'Fossil Wood Group' used in Lower Burma. Unlike many of Noetling's terms, such as 'Yenangyaungian', 'Promeian', 'Zone of so-and-so', 'Bassein series', 'Chin shales', etc., this term has flourished and prevailed over the older although less happily chosen 'Fossil Wood group' of Theobald.

Extent.

The Irrawaddy series occupies a very large tract of country in the central great synclinal basin which lies between the Arakan and Pegu Yomas. Although it contains, in a few places, pockets of clay, it is generally a deposit of soft sand-rock, always current-bedded, with interstratified brown and red earth beds, pebble beds, some hard sandstones, gravels, and conglomerates. In the south of Minbu district, in the valleys of the Man and Mon rivers, the Irrawaddy series are very full of gravel; this gravel facies is also developed in Thayetmyo and in the country to the south. Around the oilfields, gravels are quite subordinate, and soft sand-rock is by far the most predominant type.

The ferruginous conglomerate basal bed.

As has been mentioned in the preceding chapter, the basal bed in the oilfields area is a red earth or red conglomerate, or sometimes a mottled red and yellow earthy deposit. At Yenangyaung this bed is 5 or 6 feet thick, and above this there are some ferruginous conglomerates interstratified in the basal beds of the sand-rock.

This basal bed is continuous all along the western boundary of the Singu-Yenangyat fold. In the north of the Yenangyat field, some sections show a deposit that has all the appearance of laterite at this horizon. The thickness in Singu varies from two or three feet to a maximum of six feet. It has been noted in the last chapter that in the southern part of the Yenangyat field, *Batissa sethuramae* and *Taia spinifera* were found in this bed by Mr. Rau. In the extreme north of the Yenangyat fold, the basal Red Bed is well developed and is of increased thickness. It can be traced round the nose of the plunging anticline, but on the eastern boundary becomes brecciated by the fold-fault, and is finally cut out altogether. In the Gwegyo fold and the Payagyigon extension, the basal red bed is also developed; it is three or four feet thick and grades from a conglomerate to an earth.

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[1] *Rec. Geol. Surv. Ind.*, XXVIII, p. 76, (1895).

The transition in the Payagyigon extension from Irrawaddy current-bedded sandstones with a basal red bed to Pegu blue shales is very sharp; marine fossils have been found within a hundred feet of the basal red bed, and one must assume an unconformity here. The same sudden transition from current-bedded Irrawaddy sandstones to marine Yaw stage is found in the south of the Myaing fold; the Irrawaddy series overlap the Pegus completely. But to the north-west of Myaing, Pegu beds intervene between the Irrawaddy beds and the Yaws, and the Pegus are of a very shallow water facies, so that the transition is gradual. It is clear that while in some sections the Pegus are partly or even wholely denuded, in others they are fairly complete.

Unconformity marked along line Myaing-Payagyigon.

The more marked unconformities are however characteristic of the belt of country which runs through Myaing in a S. S. E. direction. This belt includes the Myaing anticline, and the Pagan and Gwegyo hills. In the northern part of Yenangyat, there are about 2,000 feet of estuarine and fluviatile Pegus under the Irrawaddy basal bed, and it is very probable that the upper part of these beds represents the Miocene. It is true that in the absence of fossils, the age is purely conjectural, but it has been shown in the last chapter that there has been a shrinkage in thicknesses of the upper beds. In Singu, Mr. Rau regards the upper Pegu beds at Singu, above the fossiliferous belt, as of Kama age, that is Miocene.

Western boundary shows slight unconformity.

Along the western margin of the great syncline of Irrawaddy beds, it is probable that the stratigraphical gap below the basal Irrawaddy conglomerates is very small.

It has been shown in Chapter IX (page 76) that the Pyalo stage is developed at the top of the Pegus in sheet 84 L/6. The stratigraphical gap is therefore negligible in this area. Further north in the same sheet near Kuyingyauk it has been mentioned that *Batissa birmanica* and *B. Kodoungensis* are found in the top zones of the Pegus. This fauna is regarded by E. Vredenburg as the estuarine equivalent of the Pyalo fauna. Again in sheet 84 K 6, *B. crawfurdi* occurs; this seems to indicate the same stage. We may, therefore, assume that a fairly complete thickness of Pegus is developed all along the western boundary, and that the unconformity is negligible.

Enormous thickness of conglomerates near Mezali.

It has been stated that the basal bed of the Irrawaddy series is a red earth or red conglomerate. This is true of the oilfields (Yenangyaung, Singu, Yenangyat) and for the Pagan and Gwegyo hills and the Myaing anticline. Along the western margin of the Irrawaddy synclinal basin, the case is not so simple. Near Mezali in sheet 84 L/7, which lies south of the area shown in the map (Plate 7), ferruginous conglomerates attain great thicknesses, up to 4,000 feet, and contain large trunks of fossil wood. Only in the upper beds are the Irrawaddy series sandy.

Changes in facies.

Although there is a gradual change of facies as one moves northwards, whereby the series becomes more of the sand-rock type, yet the ferruginous basal conglomerate still forms steep hills in the Kamedaung area in the southern half of 84 L/5. Here, large pebbles 3 to 4 inches in diameter are set in a ferruginous cement. There are many similar conglomerates overlying the basal bed. There is a little fossil wood, and some sandstones and shales with vertebrate remains in the lower beds. The Upper Irrawaddy beds are soft sandstones and buff silts, but the uppermost beds seen at Nellingontaung and Nalletaung in sheet 84 L/9 are again conglomerates and gritty sandstones with quartzite pebbles.

H. S. Bion states that the basal bed of conglomerate is up to 20 feet thick in the south of sheet 84 L/6.

Basal conglomerates on western boundary.

H. S. Bion had some difficulty in tracing the basal red bed through sheet 84 K/7. He found that it was irregularly developed, and its horizon confused by the appearance above and below of other similar beds. In sheet 84 K/7, the boundary taken by myself as the Pegu-Irrawaddy boundary was a conspicuous bed of red gravel and earth. When H. S. Bion and I compared notes, it was found that his boundary and mine joined up exactly, although he had had some uncertainly when tracing it northwards. However, in sheet 84 K/7, the Upper Pegus did not differ much from the Irrawaddy beds above; the Pegu sandstones were a deeper shade of buff, rather harder, somewhat less current-bedded, but the difference was slight. These differences were, however, found to vanish completely in sheet 84 K/6, where the Upper Pegus and the Lower Irrawaddys were exactly alike. The basal red bed was traced to a point close to the Yebok stream,[1] but was not visible in the stream itself, nor for about three miles to the north. Along this tract there was a perfectly gradual transition, and no mappable boundary, but a line was obtained by walking along the strike.

No marked boundary in Kyaw valley.

The median Pegu red bed described in Chapter IX was, however, well developed. In the north of sheet 84 K/6, on the road from Gaungbaung to Zibya, the median Pegu red bed is exceptionally thick. Above it are many thinner red beds with interstratified current-bedded sands, and these seem to be particularly numerous along the strike of the boundary, but it is impossible to identify here the bed which was fixed upon in the south as a boundary.

Median Pegu bed is base of Irrawaddian facies in north Kyaw valley.

In the sections through the Kyaukthabeik and Kyaw streams in the north-east corner of sheet 84 K/6, these red gravels are seen to be lenticular in the current-bedded sandstones. It is, therefore, quite clear that the Pegu-Irrawaddy boundary is unmappable here.

In sheet 84 K/10, there is a basal red bed which can be traced from Aingma to Tabaukkon in the centre of the sheet. This bed however is not traceable north of Aingma, and the boundary that passes Leo-chaung-te towards Moksokon in sheet 84 K 6, has been obtained by drawing a line along the strike, but it must be noted that the upper Pegus and the lower Irrawaddys in this tract are exactly alike.

There are several red beds in this area, but they are either too high or too low to coincide with the bed taken elsewhere as the boundary. East of Tabaukkon, the red bed is traceable as far as the 19th milepost on the cart-road to Myaing.

Basal red bed of Irrawaddy series again found at Tabaukkon.

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[1] That is, the stream which runs from Yebyu to the Kyaw river in the south of sheet 84 K/6.

The Pegus of this eastern portion of the sheet are of a more marine type and their facies afford some means of distinguishing them from the Irrawaddys. But the red bed fails, and the transition from Irrawaddy to Pegu is gradual, as it was in the same latitude to the west in 84 K/6. The line mapped here is the line where freshwater beds pass into shallow marine beds underneath. The boundary however is vague in the extreme, and owing to the rocks being partly obscured by soil-cap, it is very uncertain that the same horizon is being traced. For this reason it is possible that the local base of the Irrawaddys south of Myaing may be older than the base as mapped elsewhere. The discovery of good vertebrate fossils would settle this question.

It is not suggested that the base of the Irrawaddy series varies greatly; none of the freshwater beds mapped as Irrawaddy series are in my opinion likely to prove older than Vindobonian, but it is quite possible, as has indeed been suggested by Dr. Stuart, that the Akauktauktaung stage of Henzada is contemporaneous with the oldest of the Irrawaddy beds.

Age of Irrawaddy basal bed.

The base of the Irrawaddy series is regarded as Dhok Pathan stage by G. E. Pilgrim,[1] since the assemblage of vertebrates is characteristic of that stage. Dr. Pilgrim gives the following list of species of vertebrates identified from the lower Irrawaddys of Yenangyaung[2]:—

Prostegodon latidens, Clift.
Aceratherium lydekkeri, Pilg.
Hipparion punjabiense, F. & C.
Merycopotamus dissimilis, F. & C.
Tetraconodon minor, Pilg.
Hippopotamus iravaticus, F. & C.
Taurotragus latidens, Lyd.
Cervus sp.

Unconformity small at Yenangyaung.

In the Pegus beds below the red bed F. Noetling obtained a tooth which he erroneously referred to *Anoplotherium*, but which was in reality a lower molar of *Dorcatherium*. This cannot be older in Dr. Pilgrim's opinion than Lower Siwalik or Chinji age, (Tortonian).

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[1] The Lower Canine of *Tetraconodon*, *Rec. Geol. Surv. Ind.*, LX, p. 160, (1927).
[2] *Op. cit.*, XL, p. 196, (1910).

The unconformity at Yenangyaung is therefore not very great, since the vertebrate fauna of the basal Irrawaddys is referred to the Dhok Pathan stage (Pontian).

If, however, Dr. L. D. Stamp's views are to be accepted,[1] the base of the Irrawaddy sandstone at Yenangyaung may be as old as Nagri. He points out that Dr. Pilgrim in the list given above has combined the specimens from two different horizons. Dr. Stamp quotes Noetling's original description, whereby it appears that *Mastodon latidens* and *Hippopotamus irravaticus* come from higher horizons of the series at Yenangyaung, having been probably collected from the exposures along the river bank.

Dr. Stamp's view not accepted.

It seems to me, however, that the fauna, even with the exclusion of these two species, is far more likely to be of Dhok Pathan than of Nagri age. Dr. Pilgrim in the more recent of the two papers above quoted says :—

> 'Since no Nagri species has been recognised at Yenangyaung, it would be an unwarranted assumption to put the age of *Tetraconodon minor* as early as the Nagri horizon. Since the majority of fossils found belong to typical Dhok Pathan (Pontian) species, it will be better to accept that as the age of *Tetraconodon* minor.'

Base of Irrawaddy series older in Chindwin than in Yenangyaung.

In the Lower Chindwin district, near Taungbyinnge in sheet 84 J/13, which is some 35 miles north of the area shown on the map (Plate 7), Mr. A. E. Day of the Indo-Burma Petroleum Co. collected a fine series of Proboscidian teeth. All the species appeared to be new. Dr. Pilgrim identified the following :—

Mastodon cf. *M. falconeri*.
Mastodon cf. *M. angustidens* var. *palaeindicus*.
Mastodon cf. *M. pandionis*.
A specimen possibly ancestral to *Prostegodon latidens*.
A specimen recalling *Hemimastodon crepusculi*.
Listriodon pentapotamiæ.

Dr. Pilgrim concluded that the horizon was of Chinji age.[2]

From the above result, it may be inferred that the basal beds of the Irrawaddy series are older in the Lower Chindwin district than in the synclinal basin in which the three great oilfields occur.

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[1] L. D. Stamp, An Outline of the Tertiary Geology of Burma, *Geol. Mag.*, LIX, p. 498, (1922).

[2] *Rec. Geol. Surv. Ind.*, LX, p. 18, (1927).

Irrawaddian fauna in Lower Burma.

In Lower Burma, at the base of the Irrawaddy series, the following shells occur,[1] but they do not give us any indication of the exact age:—

Indonaia glyptica, Vred. & Persh.
Parreyssia latouchei, Vred. & Persh.
Acrostoma variabile (Benson).

Tatrot fauna of upper Irrawaddy beds.

Near Chaingzauk in the south-west quadrant of sheet 84 K/10, from a horizon fairly high in the Irrawaddy series, I obtained the following species:—

Stegodon clifti.
Sus giganteus.
Rhinoceros sp. cf. *sivalensis.*
Amphibos sp.
A large antelope allied to *Hippotragus.*
Teeth and horns of an antelope allied to *Boselaphus.*

There was also an enormous and ill preserved carapace of *Colossochelys atlas* in the bone bed, which was not removed.

The fauna is Pliocene and in Dr. Pilgrim's opinion represents the Tatrot stage. This agrees well with its stratigraphical position. The bed may perhaps approximate in age to the beds containing vertebrates in the river-cliff sections of Yenangyaung, where *Hippopotamus* also occurs.

Again, near Tingyokpin in the north-east quadrant of sheet 84 K/11, were found fragments of *Rhinoceros* and *Stegodon* teeth; these, although ill preserved, may well be the same species as those from Chaingzauk.

The Maw Gravels and Sands.

Discordance of Maws with Axials and Laungshes.

In sheets 84 J/4, K/1 and K/2, in the valley of the Maw river between Tilin and Gangaw, newer Tertiary sands and gravels rest unconformably upon Axials, Laungshes, and Yaw stage rocks. There is discordance between these beds and the Axials and Laungshes, upon the upturned edges of which they rest. Discordance is not marked along the junction with the Yaws, but there is a stratigraphical gap of considerable duration, representing the Oligocene portion of the Pegus.

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[1] E. Vredenburg & B. Prashad, *Unionidæ* from the Miocene of Burma, *op. cit.*, LI, p. 371, (1920).

These rocks were termed by me the 'Maw gravels'[1]. Near Tilin where they were first discovered, they are gravels and red earth beds with a little fossil wood. In the Tante stream ½ mile west of Kunze in the north of K/2, they rest unconformably upon the Cretaceous basal beds of the Laungshes. Here, the Laungshes have a moderate dip, while the gravels dip very gently to the south west. Again unconformity is seen in a section in the Maw river, ¾-mile S. S. W. of Tharaka, a village over two miles south-east of Tilin. Here gently dipping Maw gravels rest upon Axials which dip E. N. E. at 45°.

Synclinal fold.

The Maw gravels are disposed in a gentle synclinal fold, and dip gently as a rule, but in a few sections there are some steep local dips. At mile 95, furlong 3 on the high road to Gangaw, the dips in the Maws are as much as 60° in a westerly direction, but this is quite exceptional.

Lithology.

Near Tilin, the Maws are gravels mainly with some red earth. Near Ponna, about three miles beyond Tilin, they are mainly sands, and from this village to Shwekondaing, (sheet 84 K/1, mile 109 on main road) there are alternations of gravel and colour-banded sands. The colours of the sands are brick-red, buff, and bluish gray, recalling the colour-banding of the Pondaungs.

Fauna.

Vertebrate fossils were found ½-mile south-east of Shwekondaing, and ¾-mile S. by W. from the neighbouring village of Ondaw. Amongst these was a specimen of *Rhinoceros* sp. cf. *sivalensis*, with bones of crocodile. Mr. B. B. Gupta also found here *Sus titan*, Lyd. and *Mastodon hasnoti ?*, Pilg.

Sheets 84 K/1 and J/4 were mapped by Mr. B. B. Gupta. A photograph by Mr. Gupta (*see* Plate 1) shows the Maws resting unconformably upon steeply dipping Axials at a stream-section about nine furlongs west of Kinban (about the middle of sheet 84 K/1). Mr. Gupta was struck by the close resemblence of the Maw sands and gravels to the Irrawaddy series. The pebbles, of which the gravels were composed, were either quartzite or pebbles from the Axials. The size varied from one to six inches.

In the north of sheet 84 K/1 and in sheet 84 J/4, Mr. Gupta found a few bands of arenacous shale in the Maw beds; these were of a bluish green colour when fresh and were interstratified with gritty sandstones and ferruginous conglomerates. The whole series is synclinally folded, as in the Tilin area to the south. Fossil wood is abundant. Vertebrate fossils were found in the following localities:—

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[1] *Op cit.*, XLVII, p. 32, (1916).

Sheet 84 J/4.
(1) ½-mile W. S. W. of Wetchiba.
(2) ¾-mile north of Taungbyin.
(3) 1½-miles south of Lonhaw.

The following species were identified from these localities:—

Diceratherium naricum, Pilg.
Aceratherium perimense, F. & C.
Tetrabelodon falconeri, Lyd.
Hemimeryx blanfordi, Lyd.
Anthracotherium silistrense, Pent.
Dinotherium pentapotamiæ, Pilg.

The fauna from Ondaw (*Sus titan, Rhinoceros sivalensis* and *Mastodon hasnoti*) points to a Middle Siwalik, and very probably a Dhok Pathan age.

Lower Siwalik age of Lower Maw beds.

The fauna from the three localities in sheet 84 J/4 is however older, and has species in common with the Lower Manchar or Kamlial stage and with the Bugti beds. It is hardly possible to be precise about the age, but it may be Helvetian or even as old as Burdigalian. The Lower Maw beds then seem to correspond with the freshwater Pegus above the median red bed described in Chapter IX. that is, with the Upper Pegus, and perhaps the upper beds of the Maws correspond with the basal Irrawaddy beds.

There is no Tatrot age fauna in the Maws, and it may be regarded as certain that the great bulk of the Irrawaddy beds is of later age than the Maws.

Irrawaddy beds of *Chindwin and Maws may extend down to horizon of median Pegu red bed.*

It has been mentioned above that in the Chindwin district north of the area shown in the map (*see* Plate 7) the basal Irrawaddys contain a fauna which is probably of Chinji age. It would seem then possible that both the Maws and the Irrawaddys of this northern region have as their base a horizon which is represented, in the area shown in the present map, by the median red bed which splits the Pegus into an upper and a lower division. This median red bed, as the above description has indicated, is a marked feature in sheet 84 K/6, while the upper red bed, which has been taken as the basal Irrawaddy bed in the country to the south, is no longer mappable, all the beds above the median Pegu red bed being of Irrawaddy facies. It would not then be surprising to find that rocks of Irrawaddy type, but with a Lower Siwalik base, characterise the Chindwin districts. I have in a former paper shown[1] that there is a change of facies in the Tertiary deposits of Burma from marine to freshwater as one travels from south to north.

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[1] The Geotectonics of the Tertiary Irrawaddy Basin, *Journ. Asiat. Soc. Bengal*, New Ser., XIV, p. 409, (1918).

CHAPTER XII.

PLEISTOCENE AND RECENT DEPOSITS.

Two types of 'Plateau' deposits.

In the part of Burma which I am describing, the Quaternary and Recent deposits fall, as elsewhere, into two groups, an older and a newer alluvium. The old high level alluvium has been termed the 'Plateau gravel' by F. Noetling.[1] Sir E. H. Pascoe[2] has distinguished two types, the Plateau gravel proper, and the Plateau red earth, into which the gravels pass laterally in those places where the material which makes up the deposit is of a fine grain. Chipped flints are associated with these deposits, as Sir E. H. Pascoe has pointed out; these are of palæolithic type.

Sir E. H. Pascoe is inclined to regard the red earth as formed by a process which he calls 'laterosis', and he thinks that it is a deposit of sub-aerial origin. With regard to the gravels, he suggests that the pebbles are derived from the ferruginous conglomerates of the Irrawaddy series. An alternative view however is to suppose that both the pebbles in the Irrawaddy beds and those of the Plateau gravel were derived from a common or similar source.

The problem of the mode of deposition of these gravels is probably intimately connected with that of sub-recent earth-movement in Burma. This question has been discussed by Prof. J. W. Gregory, Sir E. H. Pascoe, Dr. J. Coggin Brown, and others,[3] especially in regard to the changes in river-courses. I have already discussed this question in the first chapter. Since the Plateau gravel has been very fully dealt with in Sir E. H. Pascoe's memoir, it is not necessary for me to give a fresh description.

The gravel beds of the older alluvium appear to me to be connected with the sub-recent drainage system, and I consider that they have been elevated to their present high level by uplifts, due perhaps to warping movements. Thus I regard the Plateau gravels of Yenangyaung as connected with a prehistoric Chindwin or Irrawaddy river. In Pakokku district, the gravel beds are found at high levels on either side of the Yaw river. Thus near milepost 37 on the Pakokku-Pauk road, the old gravels are exposed in a cliff section, where they lie about 100 feet above the present level of the Yaw river. At various points in sheet 84 K/7, similar gravel-beds occur at a high level, as much as three hundred feet above the Yaw. Some of these beds contain boulders up to one foot in diameter. These pebbles and boulders appear to be derived from the schistose rocks of the Axials which are so common around Kanpetlet in sheet 84 K/4.

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[1] *Mem. Geol. Surv. Ind.*, XXVII, p. 100, (1898).

[2] Oilfields of Burma, *op. cit.*, XL, pp. 48-54, (1912).

[3] For literature on sub-recent changes in the river-system of Burma, reference may be made to—*Geog. Journ.*, XXX, p. 307, and LXI, p. 166; *Mem. Geol. Surv. Ind.*, XXXIX, p. 360, (1913); *Quart. Journ. Geol. Soc.*, LXXV, p. 138, (1919); *Rec. Geol. Surv. Ind.*, XLIII, p. 178, (1913). *See* also Chap. I, page 17 of this memoir.

Plateau gravels water-borne and due to Pleistocene river action.

If, as I think, the older gravels are formed by Pleistocene river action, they are water-borne deposits; this also applies to the finer material or red earths. I therefore regard an aeolian or sub-aerial origin as unlikely. The pebbles in my view have been transported by river action from the catchment areas of the rivers; thus in my opinion the basal Irrawaddy ferruginous conglomerates are unlikely to be responsible for more than a very few of these pebbles, which probably come from the far north of Burma in the case of deposits near the Chindwin and lower Irrawaddy, and from the Yoma and Chin Hills in the case of the Yaw river area.

I have elsewhere[1] alluded to the presence of large boulders 6 to 8 feet in height, which are found in parts of Pakokku district. Perhaps these may have been brought to their present position by sudden floods.

New alluvium.

There is a large expanse of newer alluvium around Salin in sheet 84 L/10. The lake at Salin and another lake at Paunglin to the south-east are relics of a former bed of the Irrawaddy, which has changed its course, and now runs in a fairly straight line from Sale to Yenangyaung. Another broad expanse of alluvium traversed by the Yama stream lies in sheet 84 J/16.

The newer alluvium consists of sands, clays, and silts, and is very fertile.

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[1] *Journ. Asiat. Soc. Bengal*, New Ser., XIV, p. 418, (1918)

CHAPTER XIII.

STRUCTURE.

Central geosynclinal basin.

Broadly viewing the structure of the country shown in the map (*see* Plate 7), it will be observed that there is a central synclinal basin covered by Irrawaddy sandstones extending throughout most of the townships of Salin, Seikpyu, and Pauk. On the west this basin is bounded by the anticlinorum of the Arakan Yoma, with its flanking anticlines of the Nwamataung, the Yeyodaung and Dudawtaung, the Pondaung and the Ponyadaung. On the east the synclinal basin extends to the anticlinorum of the Pegu Yoma, which lies well to the east of our map, but there is a tract near the axis of the syncline, where anticlinal folding, of minor intensity, as compared with that of the great flanking folds, has brought up older rocks from beneath the Irrawaddy sandstones.

Median folding of basin.

In sheet 84 K/10, there is a gentle anticlinal swelling which causes the Pegu-Irrawaddy boundary to tongue out to the S. S. E. near Tabaukkon. If the axis of this swelling is extended to the S. S. E., the Yenangyat-Singu fold lies in the same line, as does also the Yenangyaung fold to the south in sheet 84 L/14, and the Ondwe fold still further to the south. This line of minor folding bisects the great synclinal basin from N. N. W. to S. S. E., and upon it the three great oilfields of Burma, Yenangyaung, Singu, and Yenangyat, are situated. Curiously enough the Ondwe fold has proved unproductive.

Myaing-Gwegyo folds.

Parallel with this line and to the east, about ten to twelve miles distant, another line of folding gives rise to the Myaing anticline, and the Pagan, and the Gwegyo hills and the Wetchok-Yedwet fold. It must be noted that the Gwegyo hills are aligned in echelon with the Pagan hills, but, broadly, they are to be regarded as upon the same line of folding.

While the folding along the Yenangyat-Singu-Yenangyaung line is fairly gentle, the anticlinal crests are for the most part destroyed along the line Myaing-Pagan-Gwegyo, which lies further east, and nearer to the Pegu Yoma. The Yenangyat-Singu fold, and the

Myaing, Pagan, and Gwegyo folds, are, where the eastern limb is preserved, steep on the eastern limb. The flanking anticlines of the Dudawdaung and Pondaung to the west of the basin have an exactly opposite arrangement; the steep side of the folds is the west side.

Western flanking folds.

On the west, the Nwamataung appears to be a crushed anticline structure in which the western limb has been in parts completely destroyed; along part of the Nwamataung, there is a normal succession downwards through the Eocene, without any observable reduplication.

The Yeyodaung-Dudawdaung ridge is a crushed anticline, in which the only portion where the crest is preserved is the plunging nose near Ngahlaingdwin (sheet 84 L/6). The structure of the Pondaung is similar; there is no trace of the crest, except in the plunging nose near Tazu and Letpanhla (sheet 84 K/7).

West of these flanking anticlines there are valleys between them and the Yoma or Pakokku Hill tracts; these valleys are usually occupied by Laungshe rocks which are much crushed and contorted, but in the north of sheet 84 K/ and in sheet 84 J/4, where the Maw series occurs, the folding of the Maws is gentle. The Arakan Yoma and Pakokku Hill tracts are mainly composed of Axials; these rocks are highly crushed and contorted. The photograph on Plate 2 is a typical section of the Axials.

With this preliminary sketch, the structure may now be discussed in detail.

Nwamataung range.

The Nwamataung Range.—The section through the Nwamataung, and the synclinal basin to the west is due to Mr. E. L. G. Clegg (*see* Plate 8, Sect. 1). The section is drawn due E.-W., and runs from the eastern edge of sheet 84 L/6, along latitude 20° 35′, terminating in the eastern part of the adjoining sheet 84 L/2. The dip, which is easterly at about 26° upon the Pegu-Irrawaddy boundary, increases steadily in steepness, so that on the line of the fold-fault it is about 45°. On the west of the fold-fault, the rocks are compressed into an isoclinally squeezed syncline, in which the Shwezetaw and Padaung clay stages are reduplicated. On the west of the fold-fault itself, between it and the syncline, the Yaws and the Pondaung stage are cut out. West of the syncline, the dip increases, and approaches the vertical in sheet 84 L/2 where the Tabyins, Tilins, and Laungshes outcrop. In the west of sheet 84 L/2, there is a continuation of the belt of steep and vertically dipping rocks. Mr. Clegg states that the folding and contortion in the Axials is very severe.

The Nwamataung range is peculiar in showing a perfectly normal downward succession over most of its length, while in three places, there are isolated synclines lying west of the fold-fault. The remaining two synclines lie in the south of the Minbu district and in north Thayetmyo, and are shown in the map accompanying a recent paper by Mr. E. L. G. Clegg.[1]

Three synclinal basins to west.

The presence of these three synclines can perhaps be best explained by supposing that a fold-fault runs right along the western side of the ridge of the Nwamataung. Presumably this fold-fault is dying out northwards. The Nwamataung itself dies out as a range in the south of sheet 84 K/4.

The Yeyodaung-Dudawtaung range and the Ngahlaingdwin area.—In the middle of sheet 84 L/6, a slight flattening of dip in the Pegus is noticeable. Further north this becomes a terrace, and near Ngahlaingdwin an anticlinal fold.

Ngahlaingdwin and the Dudawtaung.

A series of ten sections through the Ngahlaingdwin anticline, two of which extend westwards through the Nwamataung, is given in the Plate 25 accompanying Dr. C. Porro's paper upon this area.[2] The anticline begins as an uncrushed broad arch, of asymmetric type, with steep dips to the west, but the northern sections show that the arch is becoming narrower and more squeezed. In the median syncline between the Ngahlaingdwin fold and the Nwamadaung, the axis is very sharply bent, and there is much slickensiding, but, according to Dr. Porro, real faulting does not exist in this area.

The structure of the range is shown clearly in four sections by H. S. Bion. The first, from Kanbya to Pyindin in the south of sheet 84 L/6 is drawn along a line south of that taken by Mr. E. L. G. Clegg in his section shown on Plate 8, Sect. 1. H. S. Bion's section is shown on Plate 8, Sect. 2. The second section is drawn from near Nyaungbinywa westwards and, running north of Ngahlaingdwin, passes Kinmungyon and across the Nwamataung. (*See* Plate 8, Sect. 3). This section is similar to that of Dr. C. Porro through the same belt.

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[1] *Rec. Geol. Surv. Ind.*, LXVI, p. 250, (1933).

[2] Geology of country near Ngahlaingdwin, *op. cit.*, XLV, p. 249, (1915).

H. S. Bion's third section (*see* Plate 8, Sect. 4) is drawn through latitude 20° 54′, from Ngapya-wa in the eastern part of sheet 84 L/5 westwards. The section shows that the Dudawtaung anticline has become isoclinally squeezed. Two faults are developed, one on the western flank of the anticline in the steeply dipping and slightly reversed limb, the second lies along the axis of the median syncline. The first of these fold-faults was named by H. S. Bion the Inner Dudawtaung fault, and the second the Outer Dudawtaung fault.

The fourth section is drawn from Ngapya along an E.-W. line about two miles north of the third section. It is shown in Plate 8, Sect. 5. The structure is very similar to that shown in H. S. Bion's third section.

H. S. Bion in his diary notes says :—

'The series of parallel sections will serve to illustrate the structure of the region. It will be noticed that in the south of sheet 84 L/6, we have a continuous easterly dipping sequence from the sandstones of the Nwamataung (=Pondaung sandstones) to the Irrawaddys. In the northern part of the same sheet and the southern part of 84 L/5, the Ngahlaingdwin anticline occupies the centre of the section as a simple fold with steeper western limb (Plate 8, fig. 1). In the northern half of sheet 84 L/5, the western limb is broken by two faults, the eastern and most important being the Inner Dudawtaung fault, and the western the Outer Dudawtaung fault (*see* Plate 8, fig. 4).'

Inner and Outer Dudawtaung faults.

'As we go north from Ngahlaingdwin towards the Zaha stream, the western limb of the anticline becomes increasingly attenuated, as shown by the deduction in thickness of the Ngahlaingdwin clays (=Padaung clays) from over 1,000 feet to 200-300 feet. Where the Salin stream cuts across the anticline, the clays are probably sequeezed out altogether, and north of this point the Inner Dudawtaung fault shows the Pegus (Upper and Singu stages) in juxtaposition with the lower half of the Shwezetaw sandstones. East of Tindu, some 3,000 feet of beds have been faulted out.'

'The Outer Dudawtaung fault is a subsidiary shatter which repeats the Pegus, the line of fault being sharply defined and clear. The throw of this fault is probably between 200 and 300 feet, but in view of the absence of any reliable horizons in the Pegus, this cannot be regarded as more than approximate.'

H. S. Bion mapped the southern part of 84 K/4, but he died in Calcutta without publishing his results. E. L. G. Clegg re-examined his work, and made some notes upon the structure.[1]

The Inner Dudawtaung fault in sheet 84 K/4 describes an arc around the Seikpyu-Saw road; hence the curious V-shaped kink in the Tilin sandstones near Pyonma Sakan. The fault fades away east of Thigon. It will be also seen from the map that the outer Dudawtaung fault coalesces with the Inner east of Thonlanbyi. At the same time the median syncline swings round and terminates east of Thigon, and the succession west of the Sinle Taung (which is a northward extension of the Dudawtaung) is a normal one of monclinally dipping strata, with a regular downward succession from Pegus on the east to Laungshes near Saw. The structure somewhat recalls that of sheet 84 L/6, where there is a somewhat similar but smaller syncline west of the Nwamataung.

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[1] *Op. cit.*, LVIII, p. 45, (1925).

The Laungshes around Thigon have, according to E. L. G. Clegg, suffered greatly from folding. The dip is steep, frequently about 60°. West of Thigon, the Axials are much slickensided, broken, and contorted. They are succeeded to the east by broken sandstones, which pass upwards into the Laungshes.

Pondaung range.

The Pondaung Fold.—The structure of the Pondaung fold at its southern termination is shown in two sections accompanying my paper on the occurrence of coal-seams near the Yaw River in Pakokku.[1]

Inner and Outer Pondaung faults.

The anticline rises rapidly from the southern edge of sheet 84 K/7, and the crest becomes fractured about a mile S. S. E. of the point where the Yaw stage outcrops on the crest. The fracture is very slight at first, but increases and becomes a fault near the Yaw river. North of the Yaw river the anticlinal fault continues as the Inner Pondaung fault, while the synclinal trough between this fold and the northern continuation of the Sinle monocline (*see ante*) also becomes faulted along the axis, to form an Outer Pondaung fault. The structure is, in fact, very similar to that of the Ngahlaingdwin area. The synclinal trough is, in the south of sheet 84 K/7, an unfractured syncline, but north of the Yaw there is a sharp dislocation, which brings vertical or reversed Yaws or (further north) Pondaungs into juxtaposition with Shwezetaw sandstones dipping gently east. The Outer Pondaung fault was traced as far as Man village, and the Inner to about the same latitude, but neither were found north of this line. The syncline terminates about three miles to the north-west of Man, and the Pondaung north of this area shows a normal succession downwards as one travels from east to west, and it has a monoclinal structure.

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[1] *Op. cit.*, XLIV, p. 163, and Pl. 9, (1914).

In sheet 84 K/6, the Pondaung and the Ponnyadaung show monoclinal structure, with a regular moderate to steep easterly dip. There is a gentle syncline in the north-east corner of the sheet; the dips along the Pegu-Irrawaddy boundary are about 10°; the median Pegu red bed dips at about 25°; the Yaw stage near Kyaukmasin at about 30°; the Tabyins near Yonsin dip at about 50°, and the Laungshes in the north-west corner at 65°. Thus there is a regular increase of dip. The only exception to this arrangement is the flattening of dip in the Pondaung sandstones, which are spreading out their outcrop, so that in the sheet to the north (84 K/5) a syncline is developed between the Pondaung and the Ponnyadaung, which now branches from the Pondaung to form a separate range. All the above dips are easterly.

The Northern Pondaung and the Ponnyadaung Ranges.—The Northern Pondaung and the Ponnyadaung ranges in sheets 84 K/5 and 84 J/8 were mapped by Capt. F. W. Walker. A series of sections drawn by him illustrate the structure.

Ponnyadaung.

The first section, (*see* Plate 8, Sect. 6) is drawn about latitude 21° 55′ eastwards from just north of Sinzit. The thick black lines near the top of the Tabyins and near the base of the Yaws indicate coal-seams. The Ponnyadaung is a simple monocline, the ridge being composed of massive Pondaung sandstone. To the east of the Ponnyadaung lies the Kyaw syncline, so called from the large village of Kyaw in the middle part of 84 K/5. In this syncline the Yaw stage is exposed above the Pondaungs, and the Yaw outcrop is cut off in the south by a fault striking 80° east of north.

This fault hades at an angle of 10° northwards from the vertical. On the south side, the Pondaung sandstones form an almost vertical wall. Further east the Pondaung range has a core of Tabyin clay, and is a highly compressed anticline, overturned to the east. Still further east is the Taungbyauk syncline showing Pegu beds in the axis of the syncline, then Yaws, and then Pondaungs underlying them.

In the south of 84 K/5, where the monoclinal strata of the Pondaung break up into the Kyaw syncline, Capt. Walker describes the bedding as very irregular, so that dips in all directions can be found, and there is contortion over a considerable area.

Northern Pondaung.

Other dip-faults marked on sheet 84 K/5 are near Kin-e where the crestal outcrop of Tabyins on the northern Pondaung is displaced by a dip fault. This fault also displaces the Yaws to the east. A wrinkle in the Pegus and Yaws south-east of Kin-e causes the Yaws to be duplicated in two parallel outcrops. There is much contortion here.

The structure across the Pondaung and the wrinkle near Kin-e is shown in a section on Plate 9, Sect. 8. The section is drawn from a point about 1¼ miles E. by N. from Wabin to a point about 1¼ miles E. by N. from Nganyaung.

A paper illustrated with sections, which deals with the structure of the northern Pondaung, was published in 1923 by Dr. L. Dudley Stamp[1]. Of his three sections, one runs through Kin-e; another in the north of 84 K/5 through Kathaung, and the third in the south of 84 J/8 and J/12 runs through Mayin village. The sections reveal a similar structure to that shown in F. W. Walker's sections; it is therefore unnecessary to reproduce them here.

F. W. Walker's sections.

A section by F. W. Walker through sheet 84 J/8 runs from a point on the western margin of the sheet which is 4 miles N. N. W. of Ke Sakan rest-house; the line section runs in a direction about 10° north of east to the eastern margin of the sheet. This section is shown on Plate 9, Sect. 7. On the west is the monocline of the Ponnyadaung; then the gentle Kyaw syncline, in the centre of which is a small thickness of Shwezetaw sandstone underlain by rather thin Yaw stage rocks. Further east the Pondaung anticline is still a sharp fold, with steep eastern dips, and on the eastern margin is the western flank of the Mayin syncline.

Mayin syncline.

The Mayin syncline, which begins in the south-west corner of sheet 84 J/12, is a very gentle fold, with low dips. Dr. L. Dudley Stamp's most northerly section shows the structure of this synclinal fold. F. W. Walker's sections do not go far enough east to show it.

The Mayin syncline spreads out northwards. It is aligned on the same strike as the syncline north of Pauk, the axis of which runs along longitude 90° 30′, on the eastern margins of sheets 84 K/6 and K/5.

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[1] The Geology of Part of the Pondaung Range, *Trans. Min. Geol. Inst. Ind.*, Vol. XVII, p. 161.

Great boundary fault.

On the east of sheet 84 J/12, the Pondaungs abut upon the Irrawaddy sandstones, there being a great strike-fault between the two formations. This great fault runs from the eastern part of sheet 84 J/12 northwards for at least fifty miles to Kin on the Chindwin river. Southwards it turns S. S. E. and reaches the north-west corner of sheet 84 K/14, where it has been traced to a point about a mile S. S. E. of Hnanzigyi.

Mahudaung range and the boundary fault.

In the country north of the mapped area shown in Plate 7, this fault runs immediately east of a range of Pondaung sandstone known as the Mahudaung range. This range was examined by Sir E. H. Pascoe at two points (Yagyi in sheet 84 J/11, and Bawdibin in sheet 84 J/10). The structure of the Mahudaung was shown by Sir E. H. Pascoe to be anticlinal,[1] with dips on the west of the crest of from 12° up to 30°, rarely to 40°, and on the east of the crest with dips of 65° rising to vertical. Traced eastwards the vertically dipping Pondaungs give place to practically horizontal Irrawaddys.

Fragments of anticlinal crest.

In sheet 84 K/9, the fault between the Pondaungs and the Irrawaddys has generally obliterated the anticlinal crest, according to Mr. B. B. Gupta. The Pondaungs dip between west and south-west. In three spots however Mr. Gupta observed steep dips (from 40° to 70°) in the opposite direction. He thinks that either these dips are the relics of an anticlinal fold, or else a drag caused by the deep downthrow to the east of the fault.

Bahin and Aukkyin faults.

The Kyaukkwet Area (84 K/10), and the Myaing fold (84 K/14).—A section shown in Plate 10, sect. 13, which runs from the western edge of sheet 84 K/10 through Leochaung-te and Myauktaw, shows a monoclinal dip from the Irrawaddy sandstones to the Pondaungs. In the east of 84 K/10, a fault known as the Bahin fault displaces the Yaw stage, running in a N. N. W.—S. S. E. direction for about two miles. A section across this fault drawn through Tegyi and Aukkyin (*see* Plate 10, sect. 14) shows the structure to be a fold-faulted anticline with steeper dips on the east side. Another fault running south-east and starting close to Aukkyin brings Irrawaddys on the north-east into juxtaposition with Pegus to the south-west.

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[1] See *Mem. Geol. Surv. Ind.*, XL, pp. 141-143 and Pl. 36, (1912).

Sir E. H. Pascoe's visit was made in the year 1908, when our party had nothing to work upon but the papers of Noetling and Grimes upon upper Burma, and the old survey of Theobald for lower Burma. Nothing was known then of the divisions of the Eocene. Sir E. H. Pascoe called the rocks we now know to be Pondaung sandstones Mahudaung beds in his map with the queried name Pegu ? added. He finds that the vertically dipping Pondaung sandstones suddenly are replaced by horizontal Irrawaddys on the boundary, but he did not state whether the junction was or was not faulted.

Myaing.

The Myaing area in the north (84 K/9) shows an outcrop of Pondaungs bounded on the east side by a great strike fault which, as has been mentioned above runs north through 84 J/12 passing Yagyi and Bawdibin along the eastern side of the Mahudaung towards Kin. It was pointed out that the structure could be regarded as anticlinal, one side of the fold, that to the north-east, having collapsed. If so, the anticlinal crest has been for the most part obliterated.

In sheet 84 K/14, a section shown on Plate 10, sect. 15, runs from near Paungbin through Ywathit to Kyetmauk in a north-easterly direction; the remainder of the section is drawn due east from Kyetmauk. This section shows an anticlinal crest at Kyetmauk, but the eastern flank of the fold is for the most part faulted away, and Irrawaddys with a very gentle easterly dip abut on the fault-line. This structure is much the same as that described by Sir E. H. Pascoe for the Yagyi and Bawdibin sections to the north.

As the map shows, north of Myaing town, Yaws occur on both sides of the anticline, but the crest is destroyed by a fold-fault, which at first runs S. S. E. and, reaching the boundary of the Pondaungs and Irrawaddys east of Myaing, bends round in a south by west direction. A section south of Myaing drawn from west of Thetkegan through Kangyi is shown on Plate 10, sect. 16.

Inner and outer Myaing faults.

This section shows three strike-faults, one just west of Thetkegan, which brings the Yaws on the west side by side with Irrawaddys on the east. The Irrawaddys are folded into a small syncline, and near Kangyi there are two faults, an inner and an outer, which function in exactly the same way as the inner and outer Dudawtaung and Pondaung faults. The inner fault represents a fracture along the anticlinal crest, the anticline having been asymmetric, with steep eastern flank. The outer fault was a fracture along the synclinal axis. The Yaw beds between the two faults are vertical.

Crumpled crest.

Near Chaingzauk over a short portion of the fold the crest is preserved, and the Yaw stage is bent into miniature wrinkles as shown in the photograph on Plate 5.

In the south of the Myaing fold Yaws dipping W. S. W abut directly on Irrawaddy sandstones; there is no vertical belt of rocks along the eastern margin, and the inner and outer faults have coalesced.

The Maw and Myittha Valleys.—The valleys of the Maw and Myittha in sheets 84 K/1 and 84 J/4 were surveyed by Mr. B. B. Gupta.

Maw syncline and faults.

On Plate 9 four sections (9 to 12) by Mr. Gupta illustrate the structure. The most southerly section from west to east from the Myittha river through Yinma, shows contorted Axials and crumpled Laungshes, with a rather corrugated syncline of Maw gravels resting unconformably upon them, but with a faulted junction on the eastern margin. This line of section runs through the north of sheet 84 K/1.

The other three sections are in 84 J/4, and they show the same faulted syncline of Maw gravels unconformably overlying contorted Axials and Laungshes. The last of these sections (*see* sect. 12) is drawn in the north-east corner of sheet 84 J/4, through Kunze, and shows the junction of the Laungshes with the Tilins. This takes us to the western flank of the Ponyadaung, the structure of which has already been described.

The Yenangyat-Singu Anticline.—The Yenangyat and Singu hills were first surveyed by G. E. Grimes,[1] who mapped these hills on a scale of eight inches to the mile. The anticline is asymmetric with a steep eastern limb. Grimes observed the great difference in the thickness of the Pegus on either side of the crest.

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[1] *Op. cit.*

Discrepancy in thickness of Pegus.

These differences are tabulated by Sir E. H. Pascoe,[1] and are as follows :—

——	Thickness of Pegus west of crest.	Thickness of Pegus east of crest.
Latitude of Yenangyat village	3,740 ft.	660 ft.
Latitude of Seikkwa village . . .	3,740 ft.	320 ft.
Latitude of Sabe village	3,500 ft.	1,470 ft.

For the Singu field the difference in thickness as estimated by Mr. Rau[2] is :—Thickness west of crest 2,400 ft., east of crest (Pascoe) 1,450 ft., difference 950 ft.

Grimes's views.

G. E. Grimes explained this difference in thickness by supposing an erosion unconformity which had denuded the Pegus on the east side of the anticline without doing so, or at least not to the same extent, on the west. This view was supported by Sir E. H. Pascoe in his memoir,[3] but he suggested at the same time that attenuation caused by compression in folding was a contributory cause.

Thrust-fault and Sir E. H. Pascoe's objections.

Two years before the publication of Sir E. H. Pascoe's memoir, I had written a short paper upon the northern part of the Yenangyat field,[4] in which I suggested that the eastern boundary of the Yenangyat-Singu anticline was strike-faulted by means of a thrust-fault. In the text-figure accompanying my paper, I drew the thrust-plane at 30° inclination with the horizontal.

Although in the particular section of which my figure was a sketch, there were some dips on the line of fault at this angle, it is now quite certain that an angle of 30° with the horizontal is too low. The fold-fault, of the existence of which there is now no doubt, is inclined at angles nearer to 60° or 70° with the horizontal than 30°. Much of the objections raised by Sir E. H. Pascoe to my view are really opposed to the conception of a low angle thrust-plane. Thus he argued that such a thrust would cut the oil-sands; this objection will not apply to a steep fault.

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[1] *Op. cit.*, p. 110.
[2] *Op. cit.*, p. 321.
[3] *Op. cit.*, pp. 110-114, (1912).
[4] *Rec. Geol. Surv. Ind.*, XXXVIII, p. 302, (1910).

Nevertheless, my main theory has been substantiated. Dr. C. Porro, writing in 1915 says[1] :—

> 'I surveyed the Yenangyat anticline in 1911, and my results confirmed the investigations of Mr. Cotter, excepting that I consider that the angle of inclination of the fold-fault with the horizontal is greater than Mr. Cotter supposed.'

Thrust-fault is correct explanation.

Mr. G. W. Lepper who was in charge of the geological staff of the Burmah Oil Company in 1933, says[2] :—

> 'The Sabe-Yenangyat flexure..........The fold is strongly asymmetrical, and a thrust-fault is developed on the steep eastern flank.'

Mr. S. R. Rau, who mapped the Singu field, has an interesting passage on the nature of the strike-fault. He says[3] :—

Mr. Rau's views on the fault at Singu.

> 'The strike-fault is closely connected with the anticlinal folding. Near Thakatu Pagoda east of Block 50, where the crest is sinking rapidly, the upper ferruginous layers, unfossiliferous sandstones, and the brilliant "White Sand" of the Pegu series are observed. Here the fault ends in a fracture, the throw is slight, and the thickness of the missing beds is small. Near Moksoma Kon and in the northerly blocks, where the crest reaches its maximum elevation, the thickness of the missing beds is large, the throw has increased, and the inversion of strata is more perceptible. Where this strike-fault continues in the Yenangyat area, similar observations were made in blocks 16, 17 and 9.
>
> The direction of the fault is 20° W. of N. to 20° E. of S., and corresponds generally with that of the anticlinal axis of folding. It commences as a fracture east of block 50 N. and continues crossing from one bed to another. In blocks 56 N., 58 N., 59 N., it is almost parallel to the strike of the beds, whereas in the southerly blocks one finds several strata truncated along the fault line.'

Fault in northern Yenangyat.

In the northern part of the Yenangyat, where the anticline is sinking, the structure is very similar to that in the southern part of Singu; the Ferruginous Conglomerate (basal bed of the Irrawaddy sandstones) and the White Sand (top bed of Pegus) can be traced round the nose of the anticline, and they can be followed along the eastern boundary for about nine miles southwards, after which they are completely cut out. For the first three miles these two beds are continuous in outcrop, after which they commence to become broken, and finally only shattered remnants of these beds are seen forming a kind of large-scale breccia due to the tearing of the fold-fault. The fault breaks across the strata as it is traced south, and beginning as a slight tear, increases in throw. Finally, south of Sabe the upper Pegus and basal Irrawaddys are completely cut out, and are not again seen on the east flank of the fold until the southern termination south of Singu is reached.

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[1] *Op. cit.*, XLV, p. 265, footnote.

[2] An Outline of the Geology of the Oil-Bearing Regions of the Chindwin-Irrawaddy Valley, etc., *World Petroleum Congress*, Pre-print No. 169, p. 7, (1933).

[3] *Rec. Geol. Surv. Ind.*, LIII, p. 324, (1922).

Sections.

Sections across the Singu-Yenangyat anticline are given in Plate 31 of Sir E. H. Pascoe's memoir, but the fold-fault is not shown. A fold-fault should be inserted along the Pegu-Irrawaddy boundary.

Another diagrammatic section by Sir E. H. Pascoe through this anticline is shown in fig. 1 on page 255 of *Rec. Geol. Surv. Ind.*, Vol. XXXIV, (1906).

Pagan hills.

The Pagan and Gwegyo Hills.—The Pagan hills lie in sheet 84 K/16, and extend for 14 miles in a S. S. E. direction from a point five miles south-east of Pagan. Although the map shows them to be surrounded by Irrawaddy sandstone, the junction of Pegus and Irrawaddy beds is obscured by alluvium and soil-cap. There is a fairly constant dip to the W. S. W. at an angle of about 35° in the Pegus of these hills, but in two or three places north and south of the Naletaw stream beds are exposed dipping at 80° in the opposite direction. The fold in fact is asymmetric like that of Yenangyat, but the eastern flank has been almost completely faulted away. In this respect it resembles the Myaing fold, on the strike of which it lies.

The northern portion of the Gwegyo hills are shown in sheet 84 L/13. Two papers, one by Sir E. H. Pascoe[1] and one by myself[2], deal with the northern and southern parts of the hills respectively.

Gwegyo hills.

The hills lie in echelon and to the W. S. W. of the line of the Pagan hills. The anticline (what is left of it) is asymmetric like that of Pagan, with steep easterly dips, but the Pegus of the eastern limb are for the most part faulted away. Fragments of the crest are preserved in the north and south noses of the fold; in the north a crest can

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[1] The Northern Part of the Gwegyo Anticline, *op. cit.*, XXXIV, p. 261, (1906).

[2] The Southern Part of the Gwegyo Hills, *op. cit.*, XXXVII, p. 225, (1909).

Fragments of crest and strike-faults.

be traced from Ayadaw village northwards; in the south there is a crest from Ngashandaung village northwards for two and a half miles. Even where the crest is preserved, the thickness of Pegu beds east of the crest is very small, except in the extreme south near Ngashandaung. The western limb dips at angles of 35° to 40° to the west or W. S. W.; the beds of the eastern limb dip either vertically or steeply eastwards, but the dip quickly grades down to about 40° in the Irrawaddy sandstones.

South of Nyaungnyigin, the crest is entirely faulted away, the eastern limb consists of Irrawaddy sandstones, which are brought into juxtaposition with westerly dipping Pegus; the Pegus of the eastern limb are entirely cut out. They reappear however in the southern termination near Ngashandaung. Where the eastern limb consists of Irrawaddy beds, they tend to be concealed by alluvium, so that sections exposing them are rare.

The Great Syncline.—Dips are very low or horizontal in the great synclinal basin covered by Irrawaddy sandstones. At Tatkan in the middle of sheet 84 L, 14 the strata are horizontal.

On the western edge of sheet 84 L/9 the dip is as low as 2° westerly; to the west the strata become horizontal and rapidly acquire an easterly dip as the Dudawtaung is approached.

The southern margin of sheet 84 L, 14 shows the northern nose of the Yenangyaung dome, sections through which are given in Sir E. H. Pascoe's memoir.

CHAPTER XIV.

ECONOMIC GEOLOGY.

Petroleum.

No fresh developments except Lanywa, since 1912.

No memoir of the Geological Survey of India would be complete without some account of the commercially valuable minerals of the country surveyed. It would be possible to write a lengthy account of the oil-fields and oil-shows in Pakokku and north Minbu. But the truth is that, except for the development of the southern part of Yenangyat (the Lanywa field) as an oilfield, there has been relatively little change in the situation since Sir E. H. Pascoe wrote his memoir twenty-four years ago. Such developments as have taken place are recorded in the Quinquennial Reviews of the Mineral Production of India,[1] and in the Director's reports on the Mineral Production of India for each year; these are published annually in Part 3 of the *Records of the Geological Survey of India.*

Results of survey mainly negative.

It must be confessed that in regard to oil-prospecting this present memoir is valuable largely for its negative results; the whole country now surveyed has been carefully examined, and it seems probable from the structure and geology of the country that no important new oilfield is likely to be found.

As has been shown in Chapter XIII, the anticlinal folds in Pakokku and north Minbu are usually faulted, and their crests destroyed, except where the anticline plunges and fades out. It is only along the line Yenangyat-Singu-Yenangyaung that the anticlinal arches are unbroken; those folds to the east (Pagan, Gwegyo, Payagyigon) and the great flanking folds to the west, with the very doubtful exception of the northern Pondaung, are not suitable structurally for the storage of mineral oil.

Type of strata in which oil may be expected.

So far as we know, mineral oil in Burma characterises formations of the shallow-water marine type. Alternations of shale and sandstone, such as are found in Singu and Yenangyat, are exactly the type of strata in which mineral oil usually occurs. Many of the formations of the western ranges are not quite the type in which we might expect to find oil in good quantity. The Padaung clay is too preponderantly argillaceous; Mr. G. W. Lepper has pointed out[1] that it contains no oil-seepages. The Pondaung sandstone contains numerous oil-seepages, but it is a formation rather preponderantly sandy. I think it must be concluded that the Yenangyaung, Singu, and Yenangyat fields are suitable both structurally and by reason of the facies of the deposits; these two favourable factors together make the oilfields. But in the Yenangyat field, where the crest is high near Yenangyat and Seikkwa villages, much of the oil-bearing strata which are concealed in Singu are laid bare by denudation and have lost their stores of oil. This has been pointed out by Mr. G. W. Lepper in the paper above quoted.

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[1] See *Rec. Geol. Surv. Ind.*, XLVI, LII, LVII, LXIV and LXX.

I am not, therefore, prepared to recommend any new territory in the area now surveyed as worth testing in view both of the above considerations and especially because all the more favourable structures have already been tested at great expense, but without finding oil except in small quantity, insufficient to give any hope of commercial success.

With these preliminary remarks, I give below a list of the chief oil-seepages and gas-pools in the area surveyed. These occurrences are interesting, as indicating the distribution of the oil-bearing rocks, although they give no evidence whatsoever of the presence of oil in commercial quantity.

LIST OF OIL-SEEPAGES AND GAS-POOLS.

Oil-seepages and gas-pools.

In the Ngahlaingdwin area, (sheets 84 L/5 and L/6) there are seven seepages of oil, one in the Singu stage, one in the Shwezetaws, four in the Yaws, and one in the Pondaungs. That in the Singu stage is on the western flank of the fold, the remainder are very close to the anticlinal crest. They are shown in the map accompanying Dr. C. Porro's paper.[2]

Another seepage, mentioned by Sir E. H. Pascoe in sheet 84 L/6 lies 3¾ miles S. W. by W. from Ngahlaingdwin, and half a mile east of the Nwamataung range. This appears to be near the junction of the Pondaungs and the Yaws.

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[1] Lepper, G. W., *op. cit.*, p. 7.

[2] *Rec. Geol. Surv. Ind.*, XLV, Pl. 26, (1915).

Gas-pools with a smell of hydrogen sulphide are rather common in the Pegus in the vicinity of Ngahlaingdwin.

In sheet 84 K/4, L. V. Dalton[1] reports the occurrence of a gas-pool south-east of Kyaukswe in Tabyin clays.

In sheet 84 K/7, seepages of oil and gas occur near the top of the Pondaung sandstones. The following localities may be noted :—

(1) 1 furlong inland from the south bank of the Yaw, 1 mile east of Tazu.
(2) In the bed of the Yaw along the fold-fault, close to the above locality.
(3) Not quite half a mile south of milestone 16 on the Pauk-Pasok road.
(4) At the spring marked on the one inch to one mile map, N. N. W. of Okhmin.

In sheet 84 K/6 :—

(5) Not quite half a mile west of the north village of Tanbin.

(6) Another seepage was reported by the Burmese villagers between (4) and (5).

Localities (1) and (4) have been tested by hand-dug wells. Five dug wells were constructed near Okhmin, they were all filled with water when visited in the winter of 1913-1914, but one had about two inches of oil floating on its surface. Drilled wells have been made to test the plunging nose of the Pondaung near (1), but paying oil has not been encountered.

(7) Near margin of Pondaung sandstone and Tabyin Clay, 1¼ miles E. 35° S. of Yonsin in the north-west corner of sheet 84 K/6 there is a seepage of brownish crude oil.

(8) About the same horizon in cracks and joints in sandstone very thick tarry oil occurs. This locality is a little over 1¼ miles in a direction N. 58° E. from Yonsin.

(9) A gas-pool was seen in the Way stream about 1¾ miles N. 57° E. from Swele in the north-west corner of 84 K/6.

(10) Another similar spring was seen about 50 feet upstream from (9). The gas in (9) and (10) has a strong smell of hydrogen sulphide.

Near (7) and (8) bituminous earth was observed.

In sheet 84 K/5, Mr. B. B. Gupta has observed the following gas-pool in the Ponnyadaung monocline :—

A pool of hydrogen sulphide gas in a tributary of the Tin stream 1¾ miles N. 53° E. of Sobya. This is in Tilin sandstone and lies in the south-west corner of the sheet.

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[1] *Quart. Journ. Geol. Soc.*, LXIV, p. 615, (1908).

In the Pondaung anticline in the south of sheet 84 K/5, Mr. Gupta noted the following seepage :—

> In the Yebyu stream, a tributary of the Kyaw river, 1¾ miles W. 10° N. of Tandaw village in Pondaung sandstones, at their junction with an inlier of Tabyin clays. This seepage is on the crest of the anticlinal fold of the northern Pondaung.

In sheets 84 K/5 and J/8, in the area mapped by Capt. F. W. Walker, there are a few small gas-pools in the outcrop of Tabyins in the Ponnyadaung monocline. But in the Pondaung anticline they extend throughout the area mapped. The majority bring to the surface pebbles and a little oil. Capt. F. W. Walker has shown the positions of several of these on the one-inch maps filed in the office of the Geological Survey of India.

The more important of these seepages are :—

(1) A group of gas-pools at the southern end of the Tabyin inlier in sheet 84 K/5. These consist of a main vent with a crater two feet wide, surrounded by subsidiary vents, some of which are inactive. The gas bubbles bring to the surface a blueish grey mud, over which there is a scum of oil. Angular pebbles of sandstone, up to one inch diameter, are found lying nearby; these have been brought up with the mud. The mud flows freely and gives the water of the streams a muddy colour over long distances; this enables one to locate the seepages with ease. Other seepages in this area are gas bubbling through muddy water.

(2) Seepages in the Ngale stream on the Tabyin inlier W. N. W. of Mayin (sheet 84 J/8) and in the neighbouring Kyaukshaw stream. These seepages are so vigorous as to produce the effect of boiling. A good scum of oil forms on the ejected water.

(3) In the Pondaung sandstones in the north of sheet 84 J/8. These seepages have craters four feet in diameter, which are filled with a thick muddy liquid through which gas bubbles.

Capt. Walker, in his progress report upon sheets 84 K/5 and J/8, has the following note upon the prospects of finding oil in the northern Pondaung anticline :—

Prospects of oil in northern Pondaung.

> 'These seepages indicate that oil is contained in some of the lower beds of the anticline at least. The beds of the Tabyin clays are well adapted for containing oil with their alternating sandstones and clay or shale layers. The crushed nature and irregular structure of the anticline, with its sharp and possibly faulted crest is however highly unsuitable for the accumulation of oil. Such sharp folds generally die out as we trace them downwards, and the beds at say 3,000 feet probably form moderate anticlines. If petroliferous strata exist at such a depth, it is unlikely that the oil will have escaped. The outcrops give no indication at what horizon the oil does occur. No trace of oil was found in the Ponnyadaung

outcrop of the Tabyin clays. The prospects of the anticline for producing oil seem very small.'

Personally, I can hardly regard the prospects of finding oil in the northern Pondaung as brighter than those of the Ngahlaingdwin and Tazu areas which were tested many years ago without success.

In sheet 84 K/10, there are seepages of oil near Kyaukkwet and Suwin, but the anticlinal crest is faulted and there is considerable disturbance. Tests have been made without success.

In sheet 84 K/14, there are gas-pools one mile N. N. W. of Chaingzauk in the Yaw stage. A photograph of those is shown on Plate 6. These pools are on the faulted crest of the Myaing fold.

Pagan and Gwegyo hills.

In the Pagan hills in sheet 84 K/16, there are no oil-seepages. Near Tetma to the south of these hills an unsuccessful boring was made. To the south of the Gwegyo hills, part of which are shown in sheet 84 L/13, test-wells sunk in the Payagyigon-Ngashandaung extension struck small shows of oil, one well producing ten barrels in the first 24 hours, but the quantity produced was not sufficient for profit.

Lanywa.

The Lanywa field, although it lies in the Pakokku district, and is for administrative purposes part of the Yenangyat field, is structurally a continuation northwards across the river of the Singu field. The productive area lies on a sand-bank between Lanywa and Sitpin villages. The area has been successfully reclaimed behind a massive revetted embankment constructed by the Indo-Burma Petroleum Company. There are over 50 wells in this small but highly productive field.[1] North of this area there is a different alignment of the anticlinal crest, the Yenangyat crest to the north lying very slightly in echelon with regard to that to the south, which continues in a straight line under the river to Singu.

In the Yenangyat, field proper, the highest yield was 22·6 million gallons in 1903. In 1927, the yield was 1·8 million gallons, there having been a steady decline during the interval.

In 1928, the Lanywa field commenced to produce, and it is mainly owing to the development of this field that the figures for production from the Yenangyat (administrative) field rose in 1933 to 23·4 million gallons. In 1934, however, the decline of the Yenangyat (geological) field was arrested by further drilling, which has resulted in a small increase in production.

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[1] *Rec. Geol. Surv. Ind.*, LXX, p. 276, (1936).

Coal.

The material for this account is taken from three papers recently published upon Burmese coal occurrences,[1] and from the progress reports of Messrs. S. R. Rau, E. L. G. Clegg, B. B. Gupta and F. W. Walker. K. A. K. Hallowes traced forty-six outcrops of coal in sheets 84 K/8, L/5, and L/6. He also found nine other outcrops in south Minbu as far south as the latitude of Ngape.

Coal south of Yaw river.

Of the forty-six outcrops, seventeen are in the Yaw stage, twenty-five in the Shwezetaw sandstones, one in the Upper Pegus, one in the Padaung clays, and two in the Pondaung sandstones.

It would be tedious to repeat again this lengthy list; those who so desire may consult Mr. Hallowes's original paper. But perhaps it would be of interest to mention a few of the thicker seams. In the table given below, the first column shows Mr. Hallowes's serial number; the second column gives the sheet number, the third column the locality; the fourth the formation; and the fifth the details of the seams.

TABLE.

Serial No.	Sheet No.	Locality.	Formation.	Details of Seam.
46	84 L/6	Paung *chaung* 2 miles W. of Myaung-u.	Yaw stage	Three seams: one foot, 5 feet, and 14 inches respectively.
40	84 L/6	Tauktyabin *chaung*; E. flank of Nwamataung, S. W. of Kinmungyon.	Yaw stage	Four seams; 2 feet; 2 ft. 3 ins.; 1 ft. 9 ins.; 1 ft. 2 ins.
22	84 L/5	E. flank of Dudawtaung E. of Tindu.	Yaw stage	One seam 3 feet thick.
7	84 K/8	Wunnge *chaung* E. of Letpan Saw.	Shwezetaw sandstones.	Seam 3 ft. 4 ins. thick.

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[1] Cotter, G. de P., Some Newly Discovered Coal-Seams near the Yaw River, *op. cit.*, XLIV, p. 163, (1914).

Hallowes, K. A. K., On the Coal-Seams of the Foot-Hills of the Arakan Yoma, *op. cit.*, LI, p. 34, (1921).

Lander, C. H. and Walker, F. W., Report on the Examination of Burmese Lignites from Namma, Lashio, and Pauk, *op. cit.*, LVI, p. 362, (1925).

Only one seam of all those analysed had a fixed carbon content of over 50 per cent.; this was the sample from the Myaung-u, locality No. 46, in which the fixed carbon content was 54·32 per cent.

Not of economic value at present.

The average analysis of the coals collected by Mr. Hallowes between Letpan Yaw and Ngape was:—

	Per cent.
Moisture	17·88
Ash	18·87
Fixed carbon	32·40
Volatile matter	30·82

Calorific value, 3,913 to 4,610 calories.

Sulphur content from 0·52 to 2·50.

The above analyses show that the coal is a lignite of poor quality, moreover there are considerable partings of carbonaceous shale and sandstone in the groups of seams. It is inferior in quality to the coal of the Letpanhla and Tazu fields which I shall describe below. None of the seams can to-day be regarded as of economic value.

In sheet 84 K/7, two coalfields were described by me in the paper above quoted, that is the Letpanhla field, and the Tazu field. The coal-seams occur near the base of the Shwezetaw sandstones.

Coal of Yaw river area.

The seams are seen in the Yaw river, half a mile south-east of Letpanhla village and can be traced for about 1½ miles in a south-west direction to the crest of the Pondaung fold, which is here plunging quickly. Like the coal-seams described by K. A. K. Hallowes these seams are much interrupted by interstratified strata of sand and carbonaceous shale; this greatly increases the difficulties of developing them. On the crest of the Pondaung, 28 feet of strata contained about 13 feet of coal, that is, less than half the thickness. The thickest single seam without partings was 3 ft. 6 ins. It is not necessary to give further details; those who wish for full measurements must consult my original paper. Speaking broadly, there is one seam, which, neglecting some thin partings, is just over six feet thick; this can be traced for about half a mile, but on the Yaw river the thickness is reduced to between 4 and 4½ feet.

This same basal Shwezetaw coal outcrops also west of Tazu, and the outcrop runs to the north of the Yaw. Several outcrops of groups of seams with partings were excavated; amongst these were some seams of 3½ and 4 feet thick.

The average analysis of 22 samples of these coals was:—

	Per cent.
Moisture	18·69
Ash	11·33
Fixed carbon	35·84
Volatile matter	34·13

Calorific value, 4,499 to 4,835 calories.

Sulphur content, 2·285 to 5·628 per cent.

Poor quality.

As can readily be seen, the analysis does not greatly differ from that of Mr. Hallowes's samples to the south, although the coal is a shade better in quality. In any case it can only be regarded as a lignite of very poor quality, by reason of the high percentage of moisture, the low fixed carbon, and the frequent partings in the seams. It cannot be regarded as of economic value under present conditions.

Samples from the Letpanhla and Tazu fields were sent to the Director of Fuel Research, London, for examination. The results of this examination are given at length in the third of the three papers quoted above. Estimates are given of the amounts of tar and coke available from the specimens.

Mr. B. B. Gupta found coal seams similar in general quality to those above described in the Yaw shales in the south of sheet 84 K/5.

Other seams.

A seam, 2 ft. 2 ins. thick, was found in Pondaung sandstones in the Kyaw river, 1½ miles W. N. W. of Tandaw in sheet 84 K/5. Another seam, 2 ft. 10 ins. thick, occurs in the Yebyu tributary of the Kyaw near the last locality. The dips are very steep. Other thin coal-seams were found in the Tin, Way, and Lun streams. That in the Tin stream 2 miles north-east of Sobya was traced for four miles but was of poor quality. This seam was in Tabyin clay.

In the Laungshes, coal occurs one mile E. N. E. of Yeshin in sheet 84 K/1. The thickest seam which was very poor quality, was only 1½ feet thick.

In sheets 84 K/5 and J/8, which were mapped by Capt. F. W. Walker, the coal of the Yaw stage and of the Shwezetaw sandstone was of no importance. But there were seams in the Tabyin clay which may be mentioned. One section of this coal in the Tabyins was measured in an exposure 1¼ miles N. N. E. of Chaing in sheet 84 K/5. The thickest single seam was only 15 inches, but there were many seams in a small thickness of beds. The coal is clearly of no economic value.

In the south-west corner of sheet 84 K/9, Mr. Gupta found coal seams in the Yaws near Sinzwe, Ngamyaung, and Konywa. One seam one mile S. 10° E. of Sinzwe, which was 1 ft. 11 ins. thick, was analysed and gave an analysis comparable with the coal of Tazu and Letpanhla. None of these seams can be regarded as of economic value.

Copper Ore.

Mr. Clegg states that in sheet 84 L/1, about one mile west of Tagaunggyin at a spot where the Pakokku Hill tract boundary crosses the Mon river (*see* southern margin of sheet 84 L/1) there are agglomerates, serpentine, and an original plutonic rock probably a diorite, consisting of basic plagioclase felspar, hornblende, and a little magnetite.

Mon river.

The serpentine forms the steep western bank of the Mon, and in this is an occurrence of copper ore. It is situated about 200 feet above the river up a steep gully, and is perfectly visible from the stream below. The exposure on the cliff face is about three yards high and two yards wide, and consists on the surface of impure copper carbonate (malachite). On digging into the rock face, the serpentine is found to be much more solid and is impregnated with copper pyrites. Mr. Clegg found it impossible to get good specimens owing to the rotten and crumbly state of the rock face which threatened danger from above with every stroke of the hammer. An analysis in the laboratory of a piece of impregnated serpentine showed 11·1 per cent. of copper.

The deposit did not appear to be extensive. Mr. Clegg was informed by a villager that there was another occurrence in the hills to the west.

CHAPTER XV.

THE IGNEOUS ROCKS OF SHEET 84 J/16.

In sheet 84 J/16, in the Salingyi township of the Lower Chindwin district, there is a group of igneous rocks associated with Pegu and Irrawaddy beds; these rocks were mapped by Mr. V. P. Sondhi. I have left their description to the last, because they are on the strike of the Pegu Yoma, and are part of the Mount Popa-Shinmataung group, and on the same strike. The description of these rocks will have to be included in any memoir which may at some future time deal with the area east of that with which this memoir deals. The very brief description which I give is taken from the General Report of the Geological Survey of India for 1927 published in *Records, Geological Survey of India*, Vol. LXI, p. 103.

The lithology of the Pegu rocks differs from the type sections of the oilfields; the rock here is a calcareous bedded sandstone.

The Powin Taung in the south of the sheet consists of ashes and tuffs. Further north, there are three small elevations known as the Myayeik Taung. The main hill is composed of silicified rhyolite with blocks of quartzite on its northern side. The small hill to the west is of shattered quartzite and highly altered basalt, and in the Yamadaw stream to the south-west, there is exposed a white rock composed of decomposed felspar, in which crystals of biotite are very prominent. One mile W. S. W. of this, quartzite and basalt are exposed in a section in the Yama stream.

About one mile north of Silaung, is a plateau-like elevation about 1½ miles long and ¾-mile wide. It is composed of a dark grey olivine-basalt, unaccompanied by lapilli or tuffs. On the hill-slopes there are seen exposures of pink calcareous sinter with embedded fragments of basalt.

One mile west of Silaung Taung, another broad plateau-like elevation is covered by an old green basalt, interbedded in places with quartzite. The basalt is highly decomposed, but the interest lies in the presence of intrusive rocks.

Near Okkan, a coarse-grained white granite, composed of an equal amount of quartz and felspar with a little hornblende, is found weathering into a crumbling white earth.

One mile east of Taungbu is an occurrence of granophyre, a very compact rock, of a grey colour, with white crystals of felspar and shining quartz.

The hill marked Myetthaung Daung is composed of vesicular dark olivine-basalt with phenocrysts of augite, hornblende and plagioclase embedded in a ground-mass of the same minerals with abundant laths of felspar and interstitial glass. It appears to rest on quartzite.

Half-a-mile west of Chindaung, a granite boss is exposed which is roughly circular with a diameter of 1½ miles. This granite is very coarse-grained, white in colour, and speckled with glistening biotite. On the west it lies in contact with quartzose grit and sandstone. presumably of the Irrawaddy series. On the north there is a surface deposit of Plateau gravel.

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Silaung Taung	22	11	15	94	59	10	135.
Sinbyugyun	20	39	30	94	42	0	17.
Sinchaung	20	51	45	94	5	0	30.
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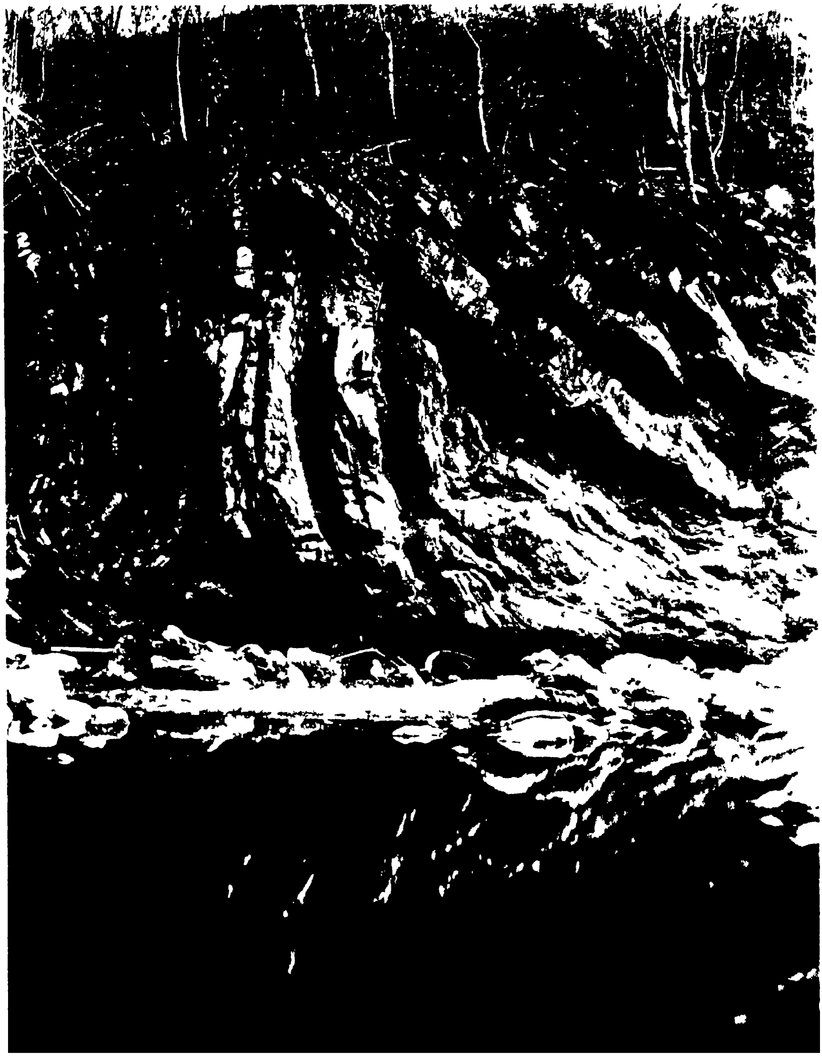
MGIPC—M—VIII-4-19—28-1-38—700.

B b Gupta, Photo *G S I., Calcutta*

UNCONFORMITY BETWEEN THE AXIALS AND MAW GRAVELS TAKEN FROM A SECTION 9 FURLONGS WEST OF KINBAN



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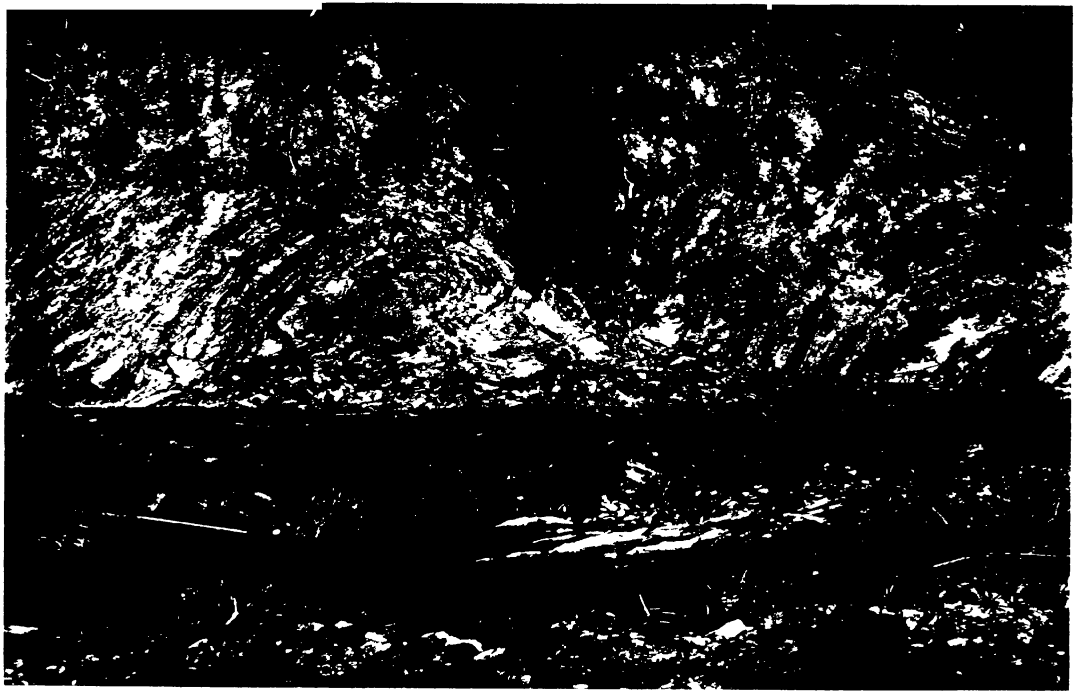
LOCAL OVERTHRUST IN AXIAL STRATA. SECTION IS TAKEN FROM A SPOT HALF A MILE NORTH-WEST OF MYAUKKON



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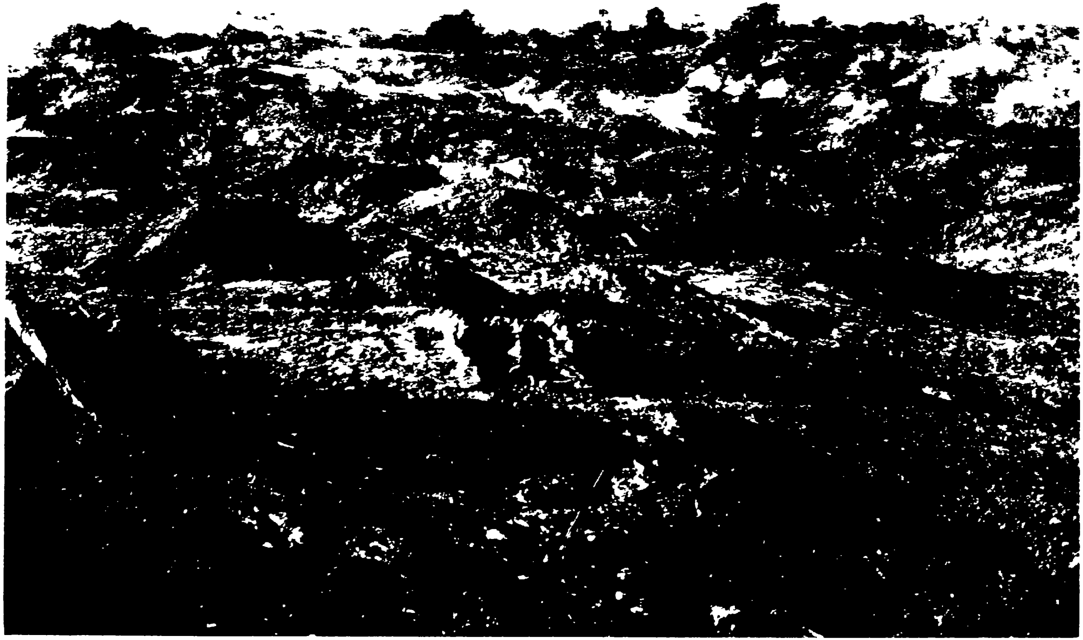
FOLDING IN THE LAUNGSHE SHALES TAKEN FROM A SECTION HALF A MILE NORTH-WEST OF YINYAUNG.

J. B. Gratt, Photo G. S. I. Calcutta

PONDAUNG CONGLOMERATE IN THE BAHIN STREAM NEAR KANLE



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THE CRUMPLED CREST OF THE MYAING ANTICLINE SHOWING THE YAW STAGE FOLDED INTO MINIATURE ANTICLINES

GEOLOGICAL SURVEY OF INDIA.

Memoirs, Vol. 72, Pl. 11.

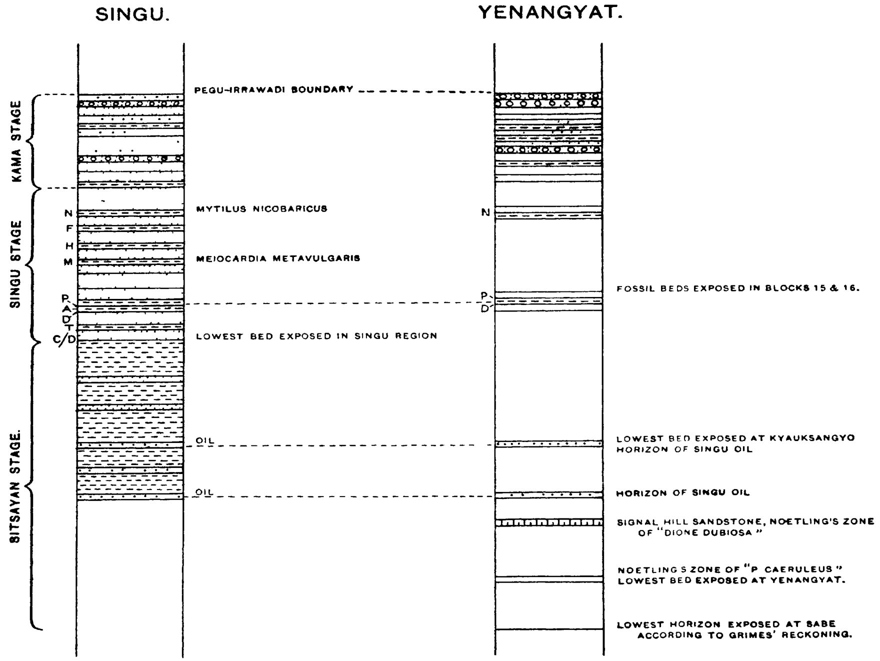
SINGU.
YENANGYAT.
KAMA STAGE
SINGU STAGE
SITSAYAN STAGE.
N
F
H
M
P
A
D
T
C/D
PEGU-IRRAWADI BOUNDARY
MYTILUS NICOBARICUS
MEIOCARDIA METAVULGARIS
LOWEST BED EXPOSED IN SINGU REGION
OIL
OIL
N
P
D
FOSSIL BEDS EXPOSED IN BLOCKS 15 & 16.
LOWEST BED EXPOSED AT KYAUKSANGYO HORIZON OF SINGU OIL
HORIZON OF SINGU OIL
SIGNAL HILL SANDSTONE, NOETLING'S ZONE OF "DIONE DUBIOSA"
NOETLING'S ZONE OF "P CAERULEUS" LOWEST BED EXPOSED AT YENANGYAT.
LOWEST HORIZON EXPOSED AT SABE ACCORDING TO GRIMES' RECKONING.

DIAGRAM SHOWING THE RELATIVE POSITION OF EXPOSED BEDS RESPECTIVELY IN THE SINGU AND YENANGYAT AREAS.

Scale, 1 inch — 1000 feet.

G. S. I., Calcutta.

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THE GEOLOGY OF PARTS OF THE MINBU AND THAYETMYO DISTRICTS, BURMA. BY E. L. G. CLEGG, B.Sc., *Superintending Geologist, Geological Survey of India.* (With Plates 12 to 17.)

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CHAPTER I.

INTRODUCTION.

Boundaries of Area described.

The area which it is proposed to describe in the following pages lies entirely on the western bank of the Irrawaddy river. It is bounded on the north by latitude 20° 30′, on the south by latitude 19° 0′ and on the east by the Irrawaddy river. On the west the boundary cannot be so definitely delineated; it runs practically parallel with and to the west of the 'Axial' boundary of the Arakan Yomas to the latitude of Kama (19° 0′).

As far north as latitude 19° 30′, the area has been previously described by Theobald[1] and mapped on the scale of 8 miles-1-inch, whilst selected isolated areas have been mapped and described by a variety of authors to whose publications reference will be frequently made in the descriptions which follow.

Theobald's classification.

In 1860 the geological survey of Pegu was commenced by Mr. W. T. Blanford and Mr. F. Fedden and was later completed by Mr. W. Theobald up to the British frontier, at that time situated about latitude 19° 30′. Theobald[2] divided up the rocks met with into the following divisions:—

I. *Newer Alluvium*	(*a*) Blown sand	Recent.
	(*b*) Littoral concrete	
	(*c*) Mangrove swamp	
	(*d*) Recent alluvium	
	(*e*) Regur	
II. *Older Alluvium*	(*a*) Older alluvium	
	(*b*) Sands and gravels	
	(*c*) Laterite	

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[1] *Mem. Geol. Surv. Ind.*, X, pt. 2, p. 189, (1873).

[2] *Ibid.*, p. 39.

III.	*Fossil-wood group*	Post-Pliocene to Pliocene.
IV.	*Pegu group*	Miocene.
V.	*Nummulitic group*	Eocene.
VI.	*Negrais Rocks*	Lower Eocene to Cretaceous.
VII.	*Mai group*	Cretaceous (Cenomanian).
VIII.	*Axial group*	Triassic (Lilang series).
IX.	*Moulmein group*	Carboniferous.
X.	*Gneiss of Martaban*	(?)

Trachyte, serpentine, granite, elvan, dykes.

The same author[1] sub-divided the Fossil-wood group in descending order into—

(*a*) Fossil-wood sands.
(*b*) Fine silty clay.
(*c*) Mogoung sands.

The 'fossil-wood sands' he defined as 'sand—in parts gravelly and conglomeratic—characterised by the profusion of concretions of peroxide of iron associated with it; fossils, trunks of silicified exogenous wood and locally mammalian bones, etc.,' the 'fine silty clay' as 'fine silty clay, with a few small pebbles mixed with sands in strings here and there, the whole very fine and homogeneous and devoid of fossils' and the Mogaung sands as 'a mixed assemblage of shales, sands and conglomerates, the last very subordinate, partaking much of the characters of (*a*) and (*b*); a little concretionary oxide of iron, fossils, rolled silicified wood, mammalian and reptilian bones and cartilaginous fish teeth. Towards the base, the beds contain marine shells and pass into those of the next group.'

His Pegu system he sub-divided into—

Kama clays—		
Prome Beds B	541	1,959 feet.
Prome Beds A	1,418	
Sitasyan shales		800 feet.

Noetling's classification.

In 1897, Dr. F. Noetling[2] in his paper on 'The Development and Sub-division of the Tertiary system in Burma' agreed that Theobald's division of the Tertiary rocks of Lower Burma into—

Younger Tertiary	Fossil-wood group. Pegu group.
Older Tertiary	Nummulitic group.

could be recognised in Upper Burma but did not consider Theobald had delineated these groups sufficiently accurately. He also considered the sub-divisions made by Theobald as having no more than a local importance. Noetling went on (p. 61) to divide the Burma Tertiaries into two main sub divisions, *viz.*:—

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[1] *Rec. Geol. Surv. Ind.*, II, pt. 4, p. 80, (1869).
[2] *Rec. Geol. Surv. Ind.*, XXVIII, pt. 2, p. 60, (1895).

1. Upper Tertiaries or Burma series.
2. Lower Tertiaries or Arrakan series.

He included in his Arrakan series—

1. the Pegu division.
2. the Nummulitic division.

Noetling remarked (p. 63) that the name 'Pegu group' was proposed by Mr. Theobald for a very important series of beds between the Eocene or Nummulitic division on the one hand, and the fossil-wood division on the other, and commented on Theobald's indefinite delineation of the fossil-wood group. He then defined the Pegu system as 'that series of beds which are between the Eocene rocks—characterised by their peculiar marine fauna and the Irrawaddi division—characterised by its peculiar terrestrial fauna.' In sub-dividing this system in Upper Burma, he inserted a Yenangyaung stage for the series of strata intermediate between the Prome stage and the fossilwood group (Irrawaddi division) owing to the marked lithological difference which distinguished the overlying series of beds from the Prome stage.

As pointed out by Pascoe[1] in describing the inlying rocks of the Upper Burma anticlines as of 'Minbu' facies, the clays of the whole series are of a light but rather intense blue when unweathered, but olive or brown when weathered for any length of time, and this lithological difference is evidently an accidental feature due to weathering and useless as a basis for stratigraphical sub-division. Pascoe[2] divided the rocks of Lower Burma relevant to the present paper into—

Pascoe's classification.

	Recent Alluvium.		Recent.
	Plateau deposits (Gravel and Red earth)		Pleistocene.
	Irrawaddi Sandstone or Irrawaddian. (Fossil-wood group)		Pliocene (including Pontian).
Pegu series	Beds above Kama Clay . . .		Miocene and Oligocene.
	Kama Clay		
	Prome Stage .	Upper . . .	
		Lower . . .	
	Sitsayan shales		
	Nummulitic series		Eocene.
	Negrais series		Eocene or Cretaceous or both.
	Mai System ('Mai'-i group of Theobald)		Cretaceous.
	Axial Beds (Axial group of Theobald) .		Cretaceous and Triassic.

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[1] *Mem. Geol. Surv. Ind.*, XL, pt. 1, p. 18, (1912).

[2] *Ibid.*, *p. 11.*

thus accepting a slight modification of Theobald's original classification. He did not agree that there was an unconformity between the Sitsayan shales and the Nummulitics as was stated by Dr. Murray Stuart[1] in his paper 'The Geology of Western Prome and Kama' wherein the latter everywhere 'succeeded with little difficulty in distinguishing the sub-divisions suggested by Theobald', *viz.*—

4. Kama clays.
3. Upper Prome series (Section B of Theobald).
2. Lower Prome series (Section A of Theobald).
1. Sitsayan shales.

but found unconformities between the Nummulitic series and the Sitsayan shales and the Pegu and Irrawaddy systems.

Stuart's classification.

Stuart discarded Noetling's Yenangyaungian and Promean stages, the former equivalent to the Kama clays and Upper Prome series, and the latter to the Lower Prome series and the Sitsayan shales, as he considered they were 'totally unsuitable both as names and divisions.' The basal beds of the Irrawaddy system according to Stuart were marine, he having fallen into the error of trying to correlate the fossil-wood group of Theobald with the Irrawaddy division of Noetling, an excusable error. The same author[2] in a paper on the 'Recorrelation of the Pegu system in Burma with Notes on the Horizon of the Oil bearing strata, including the Geology of Padaukpin, Banbyin and Aukmanein' gives the following table for the correlation of the Thayetmyo sequence with the European development.

Age.	Europe.	Burma.	
Upper Miocene .	Pontian . .	Lowest beds of the Irrawaddy series with mammalian bones. (Marine beds uncertain).	
Middle Miocene	Sarmatian . Tortonian . Helvetian .	Unconformity. Kama clays (Petroleum bearing strata).	
Lower Miocene . .	Burdigalian . .	Ditto	Pegu system.
Oligocene . .	Aquitanian . Stampian . Tongrian .	Upper Prome series . Lower Prome series . Sitsayan shales . Unconformity.	
Eocene? . . .	....	Nummulitics. (*BASSEIN SYSTEM*).	

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[1] *Rec. Geol. Surv. Ind.*, XXXVIII, p. 260, (1909).
[2] *Op. cit.*, p. 279, (1909).

In this paper Stuart merely elaborates the sequence given in his previous one.

Cotter's classification.

In 1909-10 Dr. G. de P. Cotter[1] paid a visit to the Ngape area of the Minbu district and described the stratigraphy of a section of beds along the Man river which extended from the Chin shales up to the base of the Irrawaddy system and gave descriptions of the fauna occurring in the Upper Eocene and Oligocene beds of this section. This paper in conjunction with the stratigraphy described in two later papers[2] forms the basis of the detailed stratigraphy carried out in the Nwamataung, Pondaung and Ponnyataung Ranges of the Western Minbu and Pakokku districts on which all later work in this part of Upper Burma has been based. The sequence as given by Cotter in his paper on 'The Geotectonics of the Tertiary Irrawaddy Basin' is as follows :—

Irrawaddy Series, Pontian to Pliocene. Thickness probably about 6,000 ft.

Pegu Series, Miocene.—Thickness about 8,000 ft., in south Minbu ; in Pakokku, this series and the Oligocene together are represented west of Pauk by fluviatile sandstones about 7,000 ft. thick.

Padaung Clays, Upper Oligocene. Thickness 1,500 ft., in Minbu ; represented by sandstones of fluviatile character in Pakokku.

Shwezettaw Sandstones, Lower Oligocene. –Thickness varies from 3,000 to 3,500 feet.

Yaw Shales, Upper Eocene. Thickness varies from 1,600 to 2,000 feet.

Pondaung Sandstone, Upper Eocene -Thickness varies from 3,000 to 8,000 feet.

Tabyin Clay, Middle Eocene.—Thickness about 5,000 feet.

Tilin Sandstones, Middle Eocene. –Thickness varies from 2,000 to 5,000 feet.

Laungshe Shales, Lower to Middle Eocene.- Thickness varies from 9,000 to 12,000 feet.

Paunggyi or Swelegyin Conglomerates, Lower Eocene.—Thickness varies from 2,000 to 4,000 feet.

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[1] *Rec. Geol. Surv. Ind.*, XLI, p. 221, (1912).

[2] *Rec. Geol. Surv. Ind.*, XLIV, p. 163, (1914) :
Jour. Asiat. Soc. Beng. N. S. XIV, p. 409, (1918).

Stuart's correlations of rocks of Sind, Baluchistan and Burma.

Prior to this however, but subsequent to Cotter's examination of the Pegu-Eocene succession in the Ngape area, Stuart[1] published the following table showing the correspondence of the Eocene, Oligocene and Miocene strata in Sind, Baluchistan and Burma which he stated, expressed the views shared by him with Cotter and Vredenburg.

Europe.	Sind and Baluchistan.	Burma.	
Sarmato-Pontian	Lower and part of middle Manchar and Siwaliks.	Lower part of Irrawaddy Series.	
	Second Phase of Himalayan upheaval.	Unconformity mapped as boundary between Irrawaddy and Pegus.	
Vindobonian	Upper Hinglaj	(Not known in Burma.)	Pegu Series.
	Lower Hinlaj with *Ostrea digitalina*, *O. virleti*, *O. petrosa*, etc.	Beds with *O. digitalina*, *O. crassissima etc.*= Akauktaung Series.	
Burdigalian	Uppermost Gaj; base of Bugti beds.	Frequent stratigraphical gap.	
	Gaj Beds	Prome stage and Kama clay with Gaj fossils.	
Aquitanian	Nari: Upper (with *Lepidocyclina dilatata and L. elephantina*).	Beds with *Lepidocyclina theobaldi*, *Heterostegina sp.*, etc. (Sitsayan Beds).	
Oligocene	Nari: Lower (with *Nummulites intermedius* and lepidocyclines).	*Clypeaster* Beds.	
Bartonian	First Phase of Himalayan Upheaval.		
Lutetian	Khirthar stage	Beds with *N. vredenburgi*, *N. beaumonti*, *Velates schmideli*, etc.	
	Laki stage	Beds with *N. atacicus* and *A granulosa*.	
Lower Eocene	Ranikot stage	(Not known in Burma).	

Later Vredenburg[2] published a revision of some portions of Dr Noetling's second monograph on the tertiary fauna of Burma and in this discussed the age of Noetling's post-Eocene faunas.

Vredenburg's classification of the Pegu faunas.

He obtained the following sequence for the four principal faunas dealt with by Noetling—

4. **Kama.**
3. **Singu.**
2. Minbu.
1. Yenangyat.

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[1] *Rec. Geol. Surv. Ind.*, XLI, p. 253, (1911).

[2] *Rec. Geol. Surv. Ind.*, LI, p. 224, (1920).

and found (p. 243) the Yenangyat and Minbu faunas closely connected with the lower Nari fauna of western India, the age of which is either lower Oligocene or more probably middle Oligocene, that is, approximately Stampian, the Minbu fauna being situated nearer to the upper limit of the Stampian than the fauna of Yenangyat. The Singu fauna which is shown by the stratigraphy to be newer than the Yenangyat Minbu horizon he found to be still closely related to the Nari fauna, though showing a certain admixture of forms characterising the Gáj of Western India or the Burmese equivalents of the Gáj, and therefore faunistically somewhat intermediate between the Lower Nari and the Gaj and evidently stratigraphically coinciding with the Upper Nari. He found the Kama zone as 'unquestionably the equivalent of the Lower Gáj of Western India and of the Rembang series of Java'. These conclusions were stratigraphically corroborated by the late Messrs. H. S. Bion and Sethu Rama Rau in Eastern Thayetmyo where the Kama fauna was found clearly overlying the fauna of the oil fields. Vredenburg[1] by combining the sequence of the post-Eocene beds discussed, with the classification of the Eocene established by Dr. Cotter (*ante*) obtained the following scheme for the classification of the Burma Tertiaries -

12. Irrawaddi Series, sand-stones, and clays, about 6,000 feet.	Akauktaung series, probable marine equivalents of the Irrawaddi series, sand-stones and shales, about 4,000 feet.	Pliocene and Pontian (? with Vindobonian).
11. Pyalo stage, sandstones, pebble-beds, shales about 1,700 feet (perhaps a basal member of the Akauktaung series).		Approximately Burdigalian.
10. Kama stage, shales and sandstones about 1,500 to 2,000 feet		Approximately Aquitanian.
9. Singu stage, sandstones and shales about 1,500 feet . .		Approximately Chattian.
8. Sitsayan stage, principally shales with subordinate sandstones 1,500 to 3,000 feet.		Approximately Stampian.
7. Shwezettaw stage, mostly sandstone about 3,000 feet .		Approximately Lattorfian
6. Yaw stage, largely shales, about 1,500 to 2,000 feet . .		Upper Eocene.
5. Pondaung stage, principally sandstone, 3,000 feet and more		
4. Tabyin stage, principally shales about 5,000 feet . .		Eocene.
3. Tilin stage, principally sandstones, 2,000 to 5,000 feet .		
2. Laungshe stage, principally shales, 9,000 to 12,000 feet .		
1. Paunggyi or Swelegyin stage, principally pebble beds, 2,000 to 4,000 feet.		

Vredenburg drew attention to the discrepancies between this table and the previous one published by Dr. Murray Stuart (p. 142 *ante*) for which he was largely responsible and accounted for the differences as being due to the great advance of knowledge realised during the intervening years.

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[1] *Op. cit.* p. 321.

Cotter: correlation of Pakokku and Prome areas.

In 1922, Cotter[1] published a paper to accompany a map made of the Thayetmyo area by the late Mr. H. S. Bion, and drew attention to the fact that the boundary adopted as the base of the Irrawaddies by Bion, differed from that taken by Stuart[2], and pointed out how this discrepancy had occurred; he gave the provisional table (p. 145) to show the correlation of the Thayetmyo sections with those of Pakokku, Minbu, Prome and Henzada. In this table Cotter suggested that the Sitsayan shale of Prome and Henzada was possibly the representative not only of the Padaung clay of Minbu but also of the underlying Shwezettaw stage.

Cotter pointed out objections to the stage name *Sitsayan*, since at the type locality the shales appear to be barren of fossils, and suggested that this name be discarded and the name *Padaung* adopted, as already adopted for this horizon by himself, in consultation with Messrs. G. H. Tipper and H. S. Bion.

Holland's classification and correlation of Burma Tertiaries with Java and Western India.

This has been done by Holland[3] who combines Vredenburg's correlations with the results obtained by G. de P. Cotter in Upper Burma as follows:—

——	Burma.	Java.	Western India.
Pontian	Akauktaung	Odeng	Talar.
Vindobonian	..	Tji Lanang	Upper Gáj.
Burdigalian	Pyalo	Njalingdum	
Aquitanian	Kama	Rombang	Lower Gáj.
Chattian	Singu	Not identified.	Upper Nari.
Stampian	Padaung		Lower Nari.
Lattorfian	Shwezettaw		Mula pass limestones.
Upper Eocene	Yaw and Pondaung	Nanggulan.	
Lutetian	Tabyin and Tilin	..	Kirthar.
Libyan			Laki.
Upper Cuisian	Laungshe		
Lower Cuisian	? Paunggyi or Swelegyin.		Upper Ranikot.
London Clay			
Woolwich and Reading beds+Thanet sands.			Lower Ranikot.

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[1] *Rec. Geol. Surv. Ind.*, LIV, p. 103, (1922).

[2] *Rec. Geol. Surv. Ind.*, XXXVIII, p. 259, (1910).

[3] *Mem. Geol. Surv. Ind.*, LI, p. 27, (1926).

—	Pakokku.	Minbu (West).	Thayetmyo.	Prome.	Henzada.	Stage Names after E. Vredenburg.
Upper Pegus	Deltaic and shore deposits.	Deltaic and coastal deposits.	Mogaung sands and *Turritella* sands.	Marine Irrawaddy' (Stuart, 1910).	Akauktaung beds,	***Akauktaung*** *and Pyalo.*
	Ditto . .	Deltaic and shallow marine deposits.	Kama clay ?= Padaukbin clay.	Kama clay. .	(Wanting-Stuart).	*Kama.*
Middle Pegus.	Deltaic and shore deposits.	Shallow marine deposits.	Letpanzeik beds.	Upper Prome stage	(Wanting-Stuart) .	*Singu.*
	Ditto . .	Ditto . .	Ditto . .	Lower Prome stage.	Ditto .	*Minbu.*
Lower Pegus	Deltaic and shore deposits.	Padaung clay.	*Lepidocyclina* beds.	Sitsayan shale .	*Lepidocyclina* limestone and associated Sitsayan shale.	*Sitsayan.*
	Ditto with coal seams.	Shwezettaw sandstones.	? Coal-measures of Lime Hill.	? Lower part of Sitsayan shale (doubtful no fossils).	? Lower part of Sitsayan shale.	*Shwezetaw.*
Upper Eocene.	Yaw shale . .	*Velates* beds.	? Lower shales of Lime Hill.	Not examined.	Sandstones without fossils ?	*Yaw.*
	Pondaung sandstone.	Kyet-u-bok beds with *Orthophragmina omphalus.*	*Orthophragmina* beds.	Not examined.	Unfossiliferous.	*Pondaung.*
Middle Eocene.	Tabyin clay.	Nwamataung sandstones.	Not known .	Not examined.	Unfossiliferous.	..

Attempt of Stamp to introduce Migyaungye Stage.

In 1925, Stamp[1] introduced a Migyaungye stage between the Kama stage and the Singu stage 'to demonstrate the great thickness of rocks in which the characteristic fossils of the Singu and Kama stage are found together'. Stamp gave no lists of the species characteristic of or occurring in his suggested Migyaungye stage, and as it was only after a great deal of study and by a most careful compilation of data that Vredenburg was able to separate the two distinct faunas of Kama and Singu, and then only owing to the Miocene character of the former and the Oligocene character of the latter, Burma geologists find themselves unable to accept the Migyaungye stage.

Lepper : Burma Oil Company classification.

Since then geologists of the Burmah Oil Company have made a succession of close large-scale traverses across the Pegu rocks, as mapped by myself and colleagues, from the base of the Irrawaddy sandstone series down into the Eocene and the divisions into which they found it possible to divide the rocks is given by Lepper[2] as follows :—

		Thickness (feet).
MIOCENE-PLIOCENE .	IRRAWADDY SERIES	5,000—10,000
	Unconformity.	
	PEGU SERIES.	
MIOCENE . . .	The Obogon alternations	up to 3,000
	The Kyaukkok sandstones	,, 5,000
	The Pyawbwe clays	,, 3,000
	Unconformity.	
OLIGOCENE . .	The Okhmintaung sandstones	0 to 4,500
	The Padaung clays	up to 2,500
	The Shwezetaw sandstones	2,000—4,000
	EOCENE SERIES.	
EOCENE . . .	The Yaw stage (*)†	1,000—2,000
	The Pondaung sandstones(*)†	up to 6,500
	The Tabyin clays(*)	25,000 (?)
	The Tilin sandstones*	
	The Laungshe shales*	
	The Paunggyi conglomerates*. Grits and shales below.	
	Unconformity.	
PRE-TERTIARY . .	The Axial group* of metamorphics and intrusives.	

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* As established by the officers of the Geological Survey of India.

† The Yaw Stage-Pondaung boundary is not quite the same as that mapped by the Geological Survey of India.

[1] *Geol. Mag.*, LXII, p. 518, (1925).

[2] *World Petroleum Congress*, Vol. 1, p. 16, (1933).

The inconstancy in thickness of the various divisions into which the Burma Oil Company geologists have found it possible to divide the Pegu series can be inferred from the limiting thicknesses which are given for the various divisions. The lateral variation which these wide limits imply render these divisions impossible to map as continuous entities on the old and sometimes inaccurate one-inch to the mile maps that were available south of the latitude of Minbu when I was working there, although in certain places the sequence could be recognised in a general way. I have indicated this general sequence in my map (Plate 17) by hachuring south of latitude 19° 45′, so as to make the correlation of the Pegu System which is given in the following table more obvious.

Correlation of the Pegu System at Prome, Kama, in Western Thayetmyo and in North Minbu.

Prome Latitude (18° 50′).	Kama (Lat. 19° 2′)	West of Thayetmyo (Lat. 19° 20′)	North Minbu (Lat. 20° 25′)	Burma Oil Company nomenclature (Probable correlation with)	Stage
Prome Sandstones	Upper Sandy Series	Upper Sandy Series	Upper Sandy Series	Obogon Alternations Kyaukkok sandstones	Helvetian Tortonian Burdigalian (includes Prome Sandstones).
Sitsayan Shales	Kama clays	Kama clays of Padaukpin	Shale series of Shasibo *chaung*	Pyawbwe clays	Aquitanian.
	Middle Sandy Series east of Kyaukme	Okhmintaung ridge and Monatkon sandstones	Middle Sandy Series	Okhmintaung sandstones.	Chattian.
	Padaung clays of Kyaukme	Padaung clays of Tiyo valley	Padaung clays	Padaung clays	Stampian.
	Shwezetaw sandstones (weakly developed).	Shwezetaw sandstones (weakly developed)	Shwezetaw sandstones	Shwezetaw sandstones	Lattorfian.
Eocene .	Eocene . .	Eocene .	Eocene	Eocene .	Eocene

I have given this synopsis of the development of the correlation of the Tertiary strata in Upper and Lower Burma to show the great confusion that has occurred owing to one set of mappers working from the north, southwards, and the other from the south, northwards. I had the task of joining up the isolated work of these two parties in the south-west part of the Minbu and the west of the Thayetmyo districts by mapping along the Eocene boundary in the western outcrops. This I did during the 1921-22, 1922-23, and 1923-24 field-seasons, whilst two short visits during 1935 and 1936 to west and south-west of Thayetmyo were occasioned by doubts as to the accuracy of the Pegu-Eocene boundary between Thakutkyaw (19° 18′: 94° 54′) and Thapangyo (19° 5′: 94° 57′). No faunistic evidence of Eocene rocks was known to occur along the boundary between these two places and it appeared probable that Theobald's and Murray Staurt's boundary to which I had previously concurred although mentioning this lack of evidence[1] had been placed too high.

Apart from the mapping of a large area of hitherto geologically unmapped country the stratigraphical results of my work show that the Sitsayan shales of the southern area are not only as tentatively put forward by Dr. Cotter, the equivalent of the Shwezetaw sandstones and Padaung stage of the Ngape area, but also of the Singu stage and part of the Kama stage and that the *Velates* band of the Yaw stage and the Kyet-u-bok band are homotaxial.

On the sketch plan (figure 1) are shown the various topographical one-inch sheets of the Survey of India which cover the area. With the exception of Sheets 84 L/3, 7, and 8, they were at the time of my survey all of the old style with sketched contours. The country along the western outcrops is covered by jungle at times very thick and in the Sidoktaya-Ngape-Mindon and neighbouring valleys the endemic malaria is of a particularly virulent type.

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[1] *Rec. Geol. Surv. Ind.*, LVIII, p. 45, (1926).

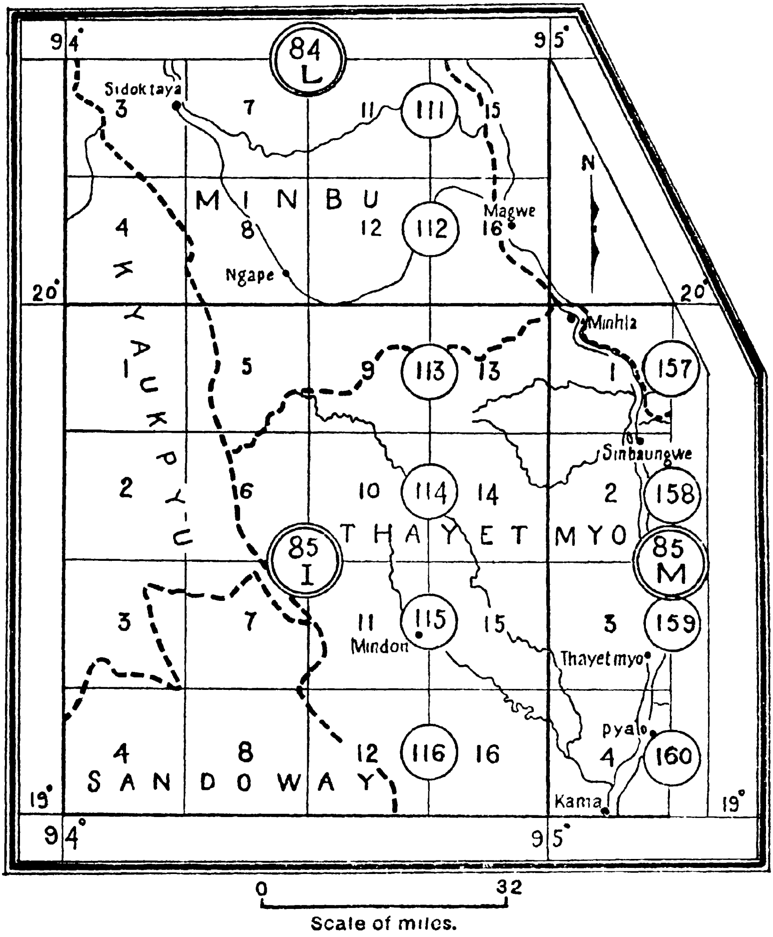

FIG. 1—Sketch map showing the numbers of the Survey of India topographical sheets covering the area described.

CHAPTER II.—PHYSICAL FEATURES, CLIMATE AND VEGETATION.

Arakan Yomas.

The whole of the area described is drained by the Irrawaddy and the tributaries which join it on the right bank, the larger of which rise in the Arakan Yoma between 40 and 50 miles to the west. In the north, the closely packed ranges of the Arakan Yoma and Nwamadaung form the western boundary; they gradually decrease in height eastwards and eventually give rise to the alluvial plains of Pwinbyu and Sagu. West of Sidoktaya (94° 14′; 15° 25′) the mountains rise steeply to the peak of Suntaung (6527) on the Arakan Yoma watershed, which runs southwards through a series of peaks of between 4,000-5,000 feet in height of which the chief are Pwegwedaung, Natyegandaung (4795), and Yeyindaung (4925). This watershed forms the western boundary of the Minbu and Thayetmyo districts and the eastern boundary of the Arakan coast districts of Kyaukpyu and Sandoway.

Nwamadaung Range.

East of Sidoktaya the Nwamadaung range rises to a height of 1620 feet in the broken mountainous ridges of the Myaung-u reserved forest. Northwards this range gradually increases in height until in the Pondaung hills of the Pakokku district it attains to 4,000 feet in the highest ridges; southwards it decreases in height for a few miles to where the gorge of the Mon river breaks through between Kyi-on and Mezali only to rise again on the south side of the gorge to a height of 1686 feet mid-way between the Mon and the Man, whence it decreases in height to the latter river east of Ngape (20° 5′; 94° 28′). Here another gorge is formed where the Man river cuts through the highest ridge of the range. Up to this point the main Nwamadaung range is formed by a number of sandstone ridge separated by deep shale valleys, the whole forming a series of scarp and dip slopes, the latter facing east and east by north. The strike of the range from being almost due north, north of the Mon, swings eastwards at that gap and at the Man crossing is found striking south-east. Thereafter, the main range loses the regularity which it has previously held but continues southwards as a high range in a general south-east by south direction, and is made up of peaks of 1201, 1300, 1388, 1383, 1692

(Kataungtaung), 1705 (Kaukketaung), 1653 (Nwalantaung), 1878 (Okhmintaung), 1298 (Ingyintaung) and 1105 (Myegyataung) feet in height.

Petering out of Nwamadaung Range.

This irregularity of the Nwamadaung range south of the Man river is due to the more intensive folding which the tertiary rocks have received on the swinging in of the Arakan Yoma to form the narrow portion of the Pegu gulf in the latitude of Prome. The squeezing has repeated the rocks forming the Nwamadaung range, and at the Man crossing and to the immediate south, the repetition is caused by faulting, but further south more normal anticlinal folding makes up the main ridge to where it peters out on the Thayetmyo-Mindon road. At this point the more westerly ridge, which has formed the western flank of the string of synclinal basins which run south from Sabagyidan on the Man river, and which has become increasingly higher and more prominent as followed southwards through the peaks of Nwalantaung (1032) Teintaung (1009) Tebingyaw (907) and Nabedaung (1323) now becomes the main hill range east of the Yomas and runs southwards to west of Kama through the high peaks of Yomakase Taung and Theobyit-taung (1494).

Country south of Thayetmyo-Mindon Road.

Although nowhere in the southern area does the ground rise above 1782 feet and to that height only in Yomakase Taung, three miles south by east of Yegyanzin, yet it is all definitely mountainous country. The valleys are all steep and deeply cut and in some places the ridges present bare dip slopes formed of grey fissured rather shaly sandstone in the joints of which, bamboo do occasionally manage to establish a precarious existence. Thi is particularly the case in the Theobyit-taung ridge north of Singaw on the Mahton chaung, and here traversing becomes a rock climb as the spurs are bare dip slopes and the streams in the rainy season a series of waterfalls. The strike of the rocks composing them does not always correspond with the direction of the hill ranges and when looking north from Kyauktan at the south-end of Theobyit-taung ridge one sees a succession of ridges, each successively westerly one extending further to the south-east so that on the 1″=1 mile map the summit of the depicted ridge crosses the strike of the rocks. This cutting across of the ridges by the bedding of the rocks is seen further north on a smaller scale in some of the occurrences of Eocene limestone.

Subsidiary ranges in this area are :—

Subsidiary Ranges.

(1) The ridge formed of intermittent limestones which crosses the Thayetmyo-Mindon Road at Mile 28, and running in a south-east by east direction climbs to over 1,000 feet in height just over a mile north-east of Thambula, and then thins out somewhat east of Thakutkyaw, where it is crossed by the Chaungmagyi *chaung*.

(2) The Theobyit-taung ridge, set back a little to the east from the above. This ridge reaches 1,495 feet in Theobyit-taung and then turning south gradually falls to 953 in Myitmyin *Taung*, its most southerly peak just north of the Mahton *chaung*.

(3) The Kado-Kadut-Taungnyo *Taung* ridge which replaces the previous one south of the Mahton *chaung*. This is a twin ridge, its easterly branch being the more prominent and attaining a height of 1,331 feet in Wetchan *Taung* before dropping to 1,099 in Taungnyo *Taung* only to vanish completely a mile and a half further to the south-east.

(4) The Yomakase *Taung* ridge. This runs south-east from south of Yegyanzin and converges on the intermittent limestone ridge aforementioned (1) to merge with the Theobyit *Taung* ridge in Myitmyin *Taung* north of the Mahton *chaung*. Northwards it forms a horse shoe bend and, turning through an angle of 180°, crosses the Mahton *chaung* east of Sagade-Ashe to run parallel with but five miles to the south-east of Theobyit *Taung* ridge. It attains a height in this western limb of 1,158 feet in Sima *Taung* and then converging on the Kado-Kadut-Taungnyo *Taung* range disappears at Mataungda.

(5) Parallel with the western limb of the preceding range are a series of rather irregular ranges all running in a general south-east by east direction. Where these have been examined they are characterised by intermittent foraminiferal limestones down to Pingadaung on the Made *chaung*. Discontinuity characterises them.

Folded ranges of riverine areas.

West of the Nwamadaung range in the extreme north of the area described lie the flat alluvial plains of Pwinbyu and Sagu but as one proceeds southwards the more intense folding of the south makes its presence felt firstly in the steeply folded anticline of Minbu which emerges from the alluvium, just north of Minbu town. Southwards this fold forms a very regular hill range of between 400-500 feet in height to latitude 20°; thereafter parallel folds are developed and give rise to the hill ranges of Laungtahletaung (1346), Padidaung, Tamansam (1264), Kyidaung, Legutaung (1485), Wunledaung (1512) and Myinbataung (1668) which strike into the Irrawaddy between Sinbaungwe and Thayetmyo. Parallel with these ranges to the west are the north-westerly pitching anticlinal hills of Mindegyi, whilst further south the Monatkon and Okpon dome sandstones form a marked feature, to re-appear again in the high Myinmagyitaung or Lime-Hill ridge which strikes the Irrawaddy river at Peikthalein. South-west from this intermittent hill range, the south-east continuation of the fold of the anticlinal ridge which terminates north of the Thayetmyo-Mindon road is again seen running parallel with and to the north-east of the Mu *chaung*. Between this latter feature and the Lime-Hill anticline, folding has been responsible for the hills five miles west of Peikthalein and at Pyalo.

Rivers.

The main drainage of the area is carried out by the Mon and the Man rivers in the north, and by the Mu (Mahton, Mindon) river with its long tributary the Pani *chaung*, and the Made river in the south. The first two rivers flow into the Irrawaddy between Yenangyaung and Minbu and the last two at Kama. All these rivers rise in the Arakan Yoma and flow for portions of their courses in the Sidoktaya-Ngape-Mindon valley, the big valley which separates the Arakan Yoma from the Nwamadaung range and its southern continuation.

Mon River.

The Mon river rises to the north-west of Sidoktaya and after emerging into the Sidoktaya valley about 30 miles north of Sidoktaya town meanders southwards to Kyion where it is joined by its main tributary the Kyi *chaung*. The head waters of this latter stream are separated by a low divide from those of the Man river sixteen miles to the south, and judging by the size of valley, the Mon must have cut back into the Sidoktaya valley and beheaded the upper reaches of the Man river within comparatively recent geological times. From Kyion the Mon cuts eastwards through the ridges which form the Nwamadaung range in a series of meanders, made up of long north-south reaches in shaly strata, and short east-west rapids through the main sandstone bands. Stretches of alluvium are found on the north-south reaches, whilst from Kyaukchat it is continuous along the river banks down to the main alluvium around Pwinbyu. Tributaries join the main stream from the north and south flowing parallel with the strike of the rocks, and the whole of the Nwamadaung range from Myaung-u (94° 21′;

20° 30′) in the north to the Kywetaga forest reserve in the south, illustrates with text-book-like perfection the development of a typical river system in a normal monocline of alternating hard and soft rocks.

Man River.

The Man river rises on the Arakan Yoma watershed due west of Ngape (20° 5′; 94° 27′) and to the north-east of Yeyindaung. Thence it maintains a general easterly course to where it cuts through the Nwamadaung range at Sabagyidan. Like the Mon, the Man meanders through the ridges of the range forming long reaches parallel with the strike, hereabouts N.W.-S.E., where flowing in soft shaly rocks, and a north-east course through the harder sandstones. Large tributaries draining the Ngape valley join the main stream from north-west and south-east of Ngape, whilst south-easterly flowing streams join the Man on its meandering course through the range. Further to the south the main range, as a range, peters out for a time where the Ngape-Minbu road traverses the hills, and this accounts for the lack of long subsequent streams joining the Man from the south-east. The meandering courses of both the Mon and Man, when cutting through the Nwamadaung range, are made up of odd pieces of consequent and subsequent streams joined up during the development and cutting back of the main streams. The lower Man river alluvium tongues up the stream from Sagu to Aingma.

Mu and Pani Rivers.

In the south the Mu *chaung* and its main tributary the Pani *chaung*, which enters it from the north about eight miles above its confluence with the Irrawaddy, maintain general south-easterly courses. They both rise close together on the Arakan Yoma watershed, and, after emerging into the Mindon valley, flow down the valley in a south by east direction for some distance. They then cut south-eastwards across the folded westerly ranges and thence meander in a south-east by south direction to the Irrawaddy north of Kama.

Apart from the aforementioned rivers, which take their rise on the watershed of the Arakan Yomas, smaller streams rise to the east of the watershed of the Nwamadaung and its southern extension, and wend their way eastwards in the north, and south-eastwards in the south, to the Irrawaddy. A noticeable feature of the drainage of the whole area is that in the northern half, the streams are all consequent on the rise of the main Nwamadaung range and seem to have so far established themselves before the more recent folding

Made chaung.

that they were able to keep pace in their erosive efforts with the rise of later hill ranges and cut right across them. In the south, where the folding has been more intense, this is not the case and one finds the rivers meandering along synclinal valleys: their channels are however deeply cut and gravels and boulders are found as terraces on the hills 200 feet above the present levels. On the Made *chaung*, which bounds the area on the south, the boulders attain quite large dimensions and consist of Axial debris. A bed of similar boulders was found at a high level in the Manaung syncline in the Minbu district, and boulders of Axial material scatter the lower-lying parts of the Eocene formations in the vicinity of Hpa-aing still further north.

Rainfall.

Both the Minbu and Thayetmyo districts lie in the 'dry zone' of Burma, the latter district bounding the 'dry zone' on the south. The rainfall is therefore small in comparison with other districts of Burma to the south, and varies from about 30 inches in the north to 40 inches in the south in the riverine area, and from 40 inches at Sidoktaya in the north-west to 60 inches at Mindon in the south-west.

Rain between December and March is uncommon although I have on occasion experienced three days continuous rain in the Thayetmyo district in December; a little rain falls in April and November but the wettest period is from May to October. Here again exceptions occur and in November, 1935, I experienced the last three of five days continuous rain when small *chaungs* were running like torrents and unmetalled roads impassable even for bullock carts.

During the cold weather the temperature at nights falls as low as 42° F, whilst in the hot weather days 107° F. is often reached.

Temperature.

The average maximum and minimum range of temperature in December is from 60° to 85°; in April, the hottest month, from 75° to 104° and in July, after the rains have established themselves, from 77° to 89°. Although the cold weather is climatically the pleasantest time of the year in the dry zone, the monsoon months from June to September are also very bearable. The rainfall usually takes place in a series of storms, but, in between storms, although the skies are at times cloudy, there is a steady south-westerly breeze and at no time is it unpleasantly hot. In fact, whilst enjoying the coolness of monsoon conditions as experienced further south, the 'dry zone' is not subject to their periods of continuous rain when clothes and boots become musty in a night, and outdoor exercise impossible. During the Monsoon the 'dry zone' is seen at its best: grass grows, albeit rather scantily, and unforested areas get a tinge of green: distant vistas of the Arakan Yomas to the west and the Pegu Yomas to the east stand out in silhouette at sunset and sunrise: and with the rise of the Irrawaddy the wide monotonous expanses of sand bank in the riverine area are submerged, whilst clumps of trees and small patches of high ground stand forth as numerous islets.

Vegetation.

The forest growth of the area is mostly determined by the climate. In the north, on the west of the alluvial plain which lies between Minbu and Salin, *Acacia catechu* and *Euphorbia* thorn scrub grow under desert conditions. To the south in the Thayetmyo district an open *Indaing* type of forest prevails, whilst further south and west the forest improves in both quality and density to the limits of the dry zone.

The ecology of this part of the 'dry zone' of Burma has been described by Stamp and Lord[1] and a general summary of their results is given in Appendix I.

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[1] L. Dudley Stamp and Leslie Lord.—The Ecology of Part of the Riverine Tract of Burma.—*Journal of Ecology* (Vol. XI, No. 2, p. 140 *et. seq.* September, 1923).

CHAPTER III.—GENERAL STRATIGRAPHY AND STRUCTURE.

North of latitude 20° 30′ the following divisions have been described by Cotter[1]: their definitions as given by Holland[2] in his Indian Geological Terminology are given below. The sequence is in ascending order :—

"*Axial Series.*– Named by W. Theobald (Rec. Geol. Surv. Ind., IV, 33, 1871) and described as the group of altered rocks constituting the main Arakan Yoma. Afterwards divided into two, the name Axial being restricted to the older division thought to be Triassic, and the name *Negrais* being applied to the younger or possibly Cretaceous division (Mem. Geol. Surv. Ind. X, 315, 1873). Although Triassic fossils occur in the Axials (Rec. Geol. Surv. Ind., IV, 39, 1871 and XXXIV, 134, 1906) the group of rocks is composite ; for among the fossils collected by Theobald and labelled "Triassic", G. H. Tipper (Rec. Geol. Surv. Ind., XXXV, 119, 1907) found specimens of *Cardita* (*Venericardia*) *Beaumonti* d'Arch., a form characteristic of beds in Sind and Baluchistan which E. Vredenburg (Rec. Geol. Surv. Ind., XXXIV, 86, 1906; XXXVI, 192, 1908) regards as Maestrichtian, reaching perhaps to Lower Danian. F. Noetling (Pal. Ind., New Ser. 1, 5, 1899-1901) refers to these rocks as the Chin series. Similar rocks have been recognised by R. D. Oldham (Mem. Geol. Surv. Ind., XIX, 223, 1883) in Manipur and the Naga Hills.

Laungshe Shales.—Occur below the Tilin sandstones in the Eocene formations of the Upper Burma Oilfields (G. de P. Cotter, Rec. Geol. Surv. Ind., XLV, 270, 1915). Examination of the fossil fauna by E. Vredenburg (Rec. Geol. Surv. Ind., LV, 53, 1923) shows that the Laungshe shales correspond essentially to the Laki (Libyan) stage, but extend down also to at least the uppermost zone of the Upper Ranikot of western India. Local conglomerates at the base of the series have been distinguished as the Paunggyi Conglomerate in the Minbu District and the Shwelegyin conglomerate in the Pakokku district.

Tilin Sandstones.—Occur below the Tabyin clays and above the Laungshe shales in Pakokku district, Upper Burma. G. de P. Cotter (Rec. Geol. Surv. Ind., XLV, 270, 1915) refers to these sandstones as containing small nummulites and apparently of Lower Eocene age, but does not precisely define the term.

Tabyin Clays.—Lie below the Pondaung Sandstones on the Yaw river, Pakokku district, and regarded by G. de P. Cotter (Rec. Geol. Surv. Ind., XLIV, 165, 1914) as Middle Eocene in age.

Pondaung Sandstones.—Underlie the Yaw shales on the Yaw river, Pakkoku district, and hence regarded by G. de P. Cotter (Rec. Geol. Surv. Ind., XLIV, 165, 1914 and LIV, 114, 1922) as Upper Eocene in age, corresponding to Cotter's bed 'H' near Ngape in the Minbu district (Rec. Geol. Surv. Ind., XLI, 224) and forming the Pondaung hill-range, north of the Yaw river. They contain a vertebrate fauna of upper Eocene age which has been described by Pilgrim and Cotter (Rec. Geol. Surv. Ind., XLVII, 42, 1916) and by Pilgrim (Pal. Ind., N. S. VIII, 3, 1925).

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[1] *Mem. Geol. Surv. Ind.*, 72, Pt. 1, (1938).

[2] *Mem. Geol. Surv. Ind.*, LI, Pt. 1, (1926).

Yaw Stage.—Named by G. de P. Cotter (Rec. Geol. Surv. Ind., XLIV, 52, 1914) from the Yaw river in the Pakokku district, Upper Burma. Regarded originally as Eocene (Kirthar) in age, corresponding to the *Velates schmiedeli* zone of near Ngape, Minbu district (cf. Rec. Geol. Surv. Ind., XLI, 221, et seq.), and occurring as marine beds below the brackish Pegus without noticeable unconformity. E. H. Cunningham Craig (Oil Finding, 1912, p. 31) refers to Yaw sandstones lying below Cotter's Yaw stage of shales as part of the Pegu series, from which Cotter differs on palæontological grounds. E. Vredenburg after study of the most recent evidence (Rec. Geol. Surv. Ind., LI, 328, 1921) regarded the Yaw stage as Upper Eocene, corresponding with the Nanggulan series of Java.

Pegu System.—Name given by W. Theobald (Rec. Geol. Surv. Ind., II, 80, 1869 and Mem. Geol. Surv. Ind., X, 268, 1873) for the beds in Burma between the Nummulitic rocks and the fossil-wood (Irrawaddy) system. Regarded originally as covering the Miocene and Pliocene periods. Theobald included in this system—

5. Sandstones and shales.
4. Kama clays.
3. Compact marly sandstone (B). } Prome beds.
2. Massive argillaceous sandstones in thick beds (A). }
1. Sitsayan shales.

F. Noetling (Pal. Ind., New Ser. 1, Mem. No. 3, 7, 1899-1901) divides these into two series—

II. Yenangyaung (including 3, 4 and 5).
I. Prome including 1 and 2.

M. Stuart (Rec. Geol. Surv. Ind., XXXVIII, 261, 1910 and XLI, 253, 1912) reverts to Theobald's scheme, objecting to the modified use of the word Prome, which Theobald applied to his sections A and B (2 and 3). Stuart, however, transfers bed No. 5 to the Irrawaddy system (*loc. cit.* 266, 267, 269) on account of an unconformity which he regards as separating 4 and 5 in the Prome district (cf. Akauktaung series).

Stuart (*loc. cit.* 279) gives the following as the ages of the divisions of the Pegu systems-

4. Kama clays. Burdigalian to Tortonian.
3. Upper Prome series (B) Aquitanian. }
2. Lower Prome series (A) Stampian. } Oligocene.
1. Sitsayan shales. Tongrian. }

E. Vredenburg (Rec. Geol. Surv. Ind., LI, 227, 1921) uses the term Pegu provisionally to mean essentially the marine beds of post-Eocene Tertiary age in the eastern part of the Arakan Yoma, in the Pegu Yoma and in the intervening Irrawaddy valley. He reviews the stratigraphical value of Noetling's Pegu zones (pp. 244-259), explains the error made by Stuart regarding the position of the Kama clays (p. 236) and, in another paper in the same volume, dealing with fossils from the Garo Hills of Assam, summarises his views regarding the correlation of the Tertiaries of Burma, Western India, Java and Europe (pp. 321-328)."

Included in the Pegu system are the following sub-divisions :—

" *Padaung Clays.*—A sub-division of the Pegu series near Ngape in the Minbu district corresponding to part of the Sitsayan shales. Distinguished by G. de P. Cotter (Rec. Geol. Surv. Ind., XLIV, 165, 1914) and named from the village Padaung (20° 2′; 94° 38′) in the Minbu district (cf. Rec. Geol. Surv. Ind., XLI, 222, and plate 21). The beds were regarded as Upper Nari in age, but by E. Vredenburg (Rec. Geol. Surv. Ind., LI, 259) were correlated with the Lower Naris (Stampian). The Padaung clays lie above the Shwezetaw Sandstones and below rocks corresponding to the Singu-Minbu stage. They correspond to some of the upper horizon of the Sitsayan shales of the Prome and Thayetmyo districts, and the term Sitsayan, when used with palæontological significance, is equivalent to Padaung, although the Sitsayan shales as a whole embrace the Shwezetaw stage below and possibly some part of the Singu stage above (Rec. Geol. Surv. Ind., LVI, p. 40). See also Kinmungyon shales.

Shwezetaw Sandstones.—Lowest division of the series on the Man river, Minbu district. Distinguished by G. de P. Cotter (Rec. Geol. Surv. Ind., XLIV, 165, 1914; Journ. As. Soc. Beng. New Ser. XIV, 416) and named from the famous pagoda at the village of Payaywa (20° 7′; 94° 34′) in the Minbu district, where these beds occur with fossils of Nari age (cf. Rec. Geol. Surv. Ind. XLI, 221 and plate 21). Poorly fossiliferous, but from the solitary *Ampullina* and its position between Eocene and Middle Oligocene, E. Vredenburg (Rec. Geol. Surv. Ind., LI, 241, 328, 1921) regards the Shwezetaw stage as Lower Oligocene (Lattorfian) in age. It is characterised by the presence of *Ampullina birmanica*, which seems to be a reliable zone fossil (Rec. Geol. Surv. Ind., LIII, 365, 368 and plates 20 and 25)."

Above the horizon of the Padaung clays officers of the Geological Survey of India have only found it possible to subdivide the remaining part of the Pegu system in a very general manner owing to the inconsistent nature of the rocks and the scale on which the survey was accomplished. Palæontologically, however, Vredenburg has subdivided the rocks into the following stages in ascending order :—

Singu stage.
Kama clays.
Pyalo stage.
Akauktaung stage.

" *Singu Stage.*—The main fossiliferous horizon of the Singu oilfield is referred to as the Singu stage by E. Vredenburg (Rec. Geol. Surv. Ind., LI, 326, 328, 1921) in correlation tables of Tertiary strata. He correlates this horizon with the Upper Nari as Chattian in age, discusses the palæontological relations with the beds in other oilfields (p. 227), and places the principal faunas of the fields in ascending order as follows :—1, Yenangyat; 2, Minbu; 3, Singu (p. 230). A later analysis of Singu fossils shows that, although they occur in separated beds, they form essentially one palæontological unit, which is mainly Oligocene, though with some Miocene types. The general facies is older than the Kama fauna, and although the lowest fossiliferous bed may be in the upper limit of the Stampian, there is a general correspondence with the Chattian stage (Rec. Geol. Surv. Ind., LIII, 339 and plate 25, 1921).

Kama Clays.—Fossiliferous blue shales and sandstones recognised by W. Theobald (Rec. Geol. Surv. Ind., II, 80, 1869; Mem., Geol. Surv., Ind., X, 273, 1873) as a constituent of his Pegu system, and named from the town of Kama (19° 0′; 95° 11″) 18 miles above Prome on the Irrawaddy River. M. Stuart (Rec. Geol. Surv. Ind., XXXVIII, 274, 1910) regards the age of these clays as Helvetian-Tortonian above and Burdigalian below, and considers them to be the uppermost of three divisions of the Pegu system separated by an unconformity from the overlying marine (Akauktaung) beds of the Irrawaddy system. Stuart (*loc. cit.* 265, 290) regards this as the main oil-bearing formation in Burma. Subsequent revision by E. Vredenburg shows that the Kama fauna corresponds approximately to the Lower Gaj (Aquitanian) of western India (Rec. Geol. Surv., Ind., LI, 230, 238, 240, 1921) higher in the local succession than the fossiliferous Singu stage (p. 232) and approximately equivalent to the Rembang series of Java (p. 243). See also Vredenburg (Rec. Geol. Surv. Ind., LIII, plate 25, 1921).

Pyalo Stage.—Name provisionally adopted by E. Vredenburg (Rec. Geol. Surv. Ind., LI, 238, 328, 1921) for beds characterised by *Ostrea latimarginata* at Pyalo on the Irrawaddy river (19° 9′; 95° 14′) and equivalent to the Upper Gaj (Burdigalian) of Western India, being above the Kama stage, (see also Vredenburg and Stuart) (Rec. Geol. Surv. Ind., XXXVIII, 127, 1909; Vredenburg, *ibid.* LIII, plate 25, 1921.)

Akauktaung Stage.—Name given by M. Stuart (Rec. Geol. Surv. Ind., XLI, 243, 244, 1912) to beds which were regarded at the time to be lying between an unconformity in Lower Burma, above the Kama clays and the 'red bed' of Upper Burma, thus including beds regarded by F. Noetling as part of the Pegu system. The beds were regarded as about Burdigalian (Lower Hinglaj) in age. Named from the Akauktaung hills (18° 30′; 95° 11′) in Henzada district. In previous publications these beds are referred to as "Marine beds of the Irrawaddy series" (Rec. Geol Surv. Ind., XXXVIII, 266, 274, etc., 1910). E. Vredenburg (Rec. Geol. Surv. Ind., LI, 251, 258, 1921) correlates the Akauktaung stage with his Talar stage of the Makran series and with the Tji Lanang, or alternatively, Odeng beds of Java, regarding the stage as Pontian or Vindobonian in age. G. de P. Cotter (Rec. Geol. Surv. Ind., LIV, 104, 1922) gives reasons for grouping the Akauktaungs with the Pegu system, and for concluding that the unconformity was erroneously identified as such by Stuart (p. 107)."

The above palæontological stages of Vredenburg correspond fairly accurately with the following lithological divisions of the Burma Oil Company which were established by a series of large scale traverses across the Pegu system in the western outcrops.

Okhmintaung sandstones.
Pyawbwe clays.
Kyaukkok sandstones.
Obogon alternations.

These sub-divisions of the Burma Oil Company geological staff are described by Lepper[1] as follows :—

" *The Okhmintaung Sandstones.*—This formation varies very greatly in thickness and is often locally absent, swelling out to thousands of feet a few miles away. The rocks consist of massive sandstones, argillaceous sandstones, grits and conglomeratic sandstones, and thin grey clays. There is evidence of overlap* by the Pyawbwe Clay and there is a well-defined palæontological break between the latter formation and the Okhmintaungs. These features, combined with evidence from exposures further east, reveal the presence of an important unconformity in the uppermost parts of the Oligocene in Burma. There is no sharp discordance of dip and strike at the break. The Okhmintaung Sandstone fauna is believed to be of Chattian age.

The Pyawbwe Clays.—These consist mainly of grey to blue sandy clays with characteristic concretionary structures, but contain several thin sandstones. Gypsum is common. Fossils are numerous and reveal the lower Miocene (Aquitanian) age of the group. The formation has been mapped from Lat. 18° 45′ to 21° 30′ in the Western Outcrops and has been identified in the main oilfields areas and elsewhere. North of Lat. 20° 50′ in the western monocline the clays are largely replaced by arenaceous beds of continental facies, and fossils are rare.

The Kyaukkok Sandstones.—These form a remarkably persistent group of yellowish-brown massive sandstones often revealing spheroidal concretions on weathering, with subordinate grey and blue sandy shales. It includes the Prome Sandstones of Theobald (Geological Survey of India) and part of the highest Pegu sandstone of the central oilfields. Fossils are abundant and the assemblage which is very characteristic, with a preponderance of lamellibranchs, indicates a Middle Miocene (Burdigalian) age. The stage has been found in the western outcrops and elsewhere from Lat. 18° 30′ to Lat. 21° 30′ but north of 20° 45′ fossils are rare and the formation gradually assumes a continental facies and contains many quartz conglomerates. North of Lat. 21° there is a local unconformity at the base of this formation but in general it is conformable to the Pyawbwe Clays.

The Obogon Alternations.—These form a dominantly arenaceous group of rapidly alternating thin beds of sand and sandy shale or clay. Conglomerates and purple shales are developed north of Lat. 20° 15′. South of about Lat. 20° marine fossils are found, indicative of an Upper Miocene (Helvetian-Tortonian) age. This stage is often missing to the north owing to the pre-Irrawaddian unconformity.

Regarding the general characteristics of these sub-divisions Lepper notes—

Lateral Variation of Strata.—It is important to note that each and every member of the Pegu succession in the Western Outcrops becomes more arenaceous northwards. Even the clay groups become thinner, and sandstones and conglomerates develop in them. Lignites and then silicified wood appear in some of the sandstones. These changes begin in lower latitudes, *i.e* , further south, in the sandstone groups than they do in the argillaceous formations. Conversely when traced southwards the groups assume a deeper water facies with fewer fossils, and the clays become thicker.

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[1] Proceedings World Petr. Congress Vol. I, London, (1933).

* I did not note any such overlap where I saw the two formations in the western part of Thayetmyo. [Author.]

Holland (*loc. cit.*) describes the Irrawaddy system as follows :—

Irrawaddy System.—Name adopted by F. Noetling (Rec. Geol. Surv. Ind., XXVIII, 76, 1895) roughly to correspond in Burma to the "Fossil-wood group" of W. Theobald (Rec. Geol. Surv. Ind., II, 79, 1869 ; Mem. Geol. Surv. Ind., X, 247, 1873). In 1869 Theobald regarded the age of the beds as probably Miocene but inclined in 1873 to the arguments of W. T. Blanford (Journ. As. Soc. Beng. XXXI, 225, 1862) in favour of a younger age, which he gave as Pliocene to 'Post-Pliocene.' Noetling (Rec. Geol. Surv. Ind., XXVIII, 76) included in the Irrawaddy system "all beds above the Yenangyaung stage which are characterised by the remains of terrestrial and fluviatile animals, but below the unconformity which separates the post-tertiary from those of tertiary age". M. Stuart from evidence collected in Western Prome, (Rec. Geol. Surv. Ind., XXXVIII, 271, 1910) concluded that the Irrawaddy system in that area should be extended down to include marine beds which are said to be separated from the Kama clays of the Pegu system by a supposed unconformity. These "Marine Irrawaddy" beds were afterwards distinguished by Stuart under the name Akauktaung series. (Rec. Geol. Surv. Ind., XLI, 243, 244, 1912). The lowest beds of the Irrawaddy system near Yenangyaung contain a fauna which, according to G.E. Pilgrim (Rec. Geol. Surv. Ind., XL, 196, 1910) is of Middle Siwalik age, or equivalent to the Pontian of Europe. G. de P. Cotter (Rec. Geol. Surv. Ind., LIV, 115, 1922) sums up the evidence which indicates that whilst the base of the Irrawaddy system may correspond with the Upper Pontian, the bulk of the beds are Pliocene in age, the "Marine Irrawaddy" beds are thus removed and transferred to the Pegu system below.

In the descriptions which follow I have returned to Theobald's original definition of the Axial series as the group of altered rocks constituting the main Arakan Yoma, regarded the Pegu system as essentially marine beds of Post-Eocene Tertiary age, and the Irrawaddy system as all consolidated rocks above the Pegu system characterised by terrestrial and fluviatile remains. I have also given certain reasons for doubting whether Triassic rocks have been proved to occur in the Axials.

Divisions of Eocene Rocks mapped.

The Eocene rocks in the area described are not divisible into the divisions mentioned above. At latitude 20° 30′ the Tilin sandstone peters out north-east of Sidoktaya (20° 27′ ; 94° 14′) and the Laungshe shales, and Tabyin clays have been grouped as the Lower Eocene. Similarly the Yaw stage has been grouped with the Pondaung sandstones as Upper Eocene, as, although distinguishable as a separate entity around the south end of the Pazawbya (20° 29″ ; 94° 18′), syncline in the extreme north, it does not persist as a distinct feature southwards along the main range. At the Mon *chaung* crossing (lat. 20° 23′) a fossil band containing the characteristic Yaw stage *Velates* occurs and again south of the Man *chaung* (lat. 20° 5′) where a Yaw stage fossil band forms a very useful tracer horizon for marking the boundary between Eocene and Oligocene rocks. South of Latitude 20° it becomes impossible to mark a boundary between even the Lower and Upper Eocene rocks and the whole of the Eocene rocks have been mapped as one unit from here to the south.

Divisions of Pegu system recognised.

Similarly, owing to the southerly shaling up of the rocks of the Pegu system, it became impossible to continue the Shwezetaw and Padaung sub-divisions of the Pegu rocks on the scale on which I was working, although where work was commenced on the Salin-Sidoktaya (lat. 20° 30′) road it was possible to recognise in the unrestricted Pegu system the following five sub-divisions in descending order—

- Pegu system
  - Pegu system restricted
    - Upper Sandy Series containing selenite.
    - Shaly series of Shasibo nala.
    - Middle Sandy and Limy series.
  - Padaung Clays.
  - Shwezetaw Sandstones.

Between the Mon river (Lat. 20° 20′), and Latitude 19° 45′, the rocks of the Pegu system remote from the Eocene-Pegu boundary were mapped by Dr. Cotter and Mr. Sethu Rama Rau, but where I traversed across them about Lat. 19° 55′, they occupy flat and featureless country characterised throughout by shales reinforced by thin bands of sandstone and no sub-divisions could be recognised in them.

Pegu system south of Latitude 19° 45′.

South of Latitude 19° 45′ the base of the unrestricted Pegu system is characterised by a sandy series, the middle by thick shales and the uppermost rocks by another sandy series. These characteristic zones can be recognised southwards in the western outcrops to Talokyin (19° 35′; 94° 55′) where a great deal of faulting takes place in broken forest country.

Okhmintaung Ridge series.

South of Talokyin the Okhmintaung ridge is formed at the base by shaly crumbly blue sandstones which weather conchoidally, a blue unfossiliferous sandstone series containing harder bands in the middle, and shelly sandstones alternating with soft fawn sandstones or shales at the top. The series is underlain by shales in the Tiyo valley and overlain by shales in the Nyaungwaing (19° 32′ ; 94° 57′) valley and has developed in the middle of the middle shaly series of the Pegu system seen further north. To the south this Okhmintaung ridge series cannot be recognised very far on the 1″ scale map, but it is distinguishable once again south-south-west of Kyaukkyi (19° 21′ ; 94° 57′) and develops a great thickness north-north-west of Singaw (19° 13′ ; 94° 56′) ; it forms the greater part of the Middle to Lower Pegu outcrops in the Mindon *chaung* above Singaw, whilst, in the area to the south-west of the same place, it exists as a well defined anticline in the Wetchan *Taung* ridge, and in a syncline to the west. The Wetchan *Taung* anticline pitches out west of Thapangyo (19° 5′ ; 94° 57′) whilst the sandstones of the western flank of the syncline continue to the south-east and cut across the Made *chaung* east of Kyaukme (19° 1′ ; 94° 59′).

Correlation of Kama area with Eastern Thayetmyo.

This sandstone is of great importance as it contains, east of Tiyo, (19° 32′ ; 94° 55′), a Singu fauna, whilst, overlying the shale series which occurs above it ; is a series of alternating hard and soft fossiliferous sandstones with occasional shale intercalations. From the base of this alternating series on the Mindon *chaung* one-third and half a mile east of Myohla (19° 13′ ; 94° 57′) respectively, Kama faunas were obtained. The sandstones series of which this latter fossiliferous alternating sequence forms the base, continues to the south to form the Prome sandstones mapped by Murray Stuart south of Kama (19° 2′ ; 95° 6′), and is overlain by an alternating sequence along the western flank of the Mindon *chaung* syncline.

Eastwards from their first occurrence south of Talokyin, the Okhmintaung ridge series, after passing under the shales of the Nyaungwaing valley, rise to form the outer sandstones of the Monatkon and Okpon domes in which Singu faunas were also obtained. These sandstones can be correlated directly with the anticlinal sandstones of Singu age mapped by Mr. Sethu Rama Rau further east. In the shaly series overlying this middle sandy one in Eastern Thayetmyo Mr. Sethu Rama Rau collected rich faunas from the following places :—

Tittabwe (19° 31′ ; 95° 28′)
Thanga (19° 32′ ; 95° 23′)
Myaukungon (19° 31′ ; 95° 24′)

Myauktin (19° 26′; 95° 22′)

Dalabe (19° 37′; 95° 17′)

and it was from these faunas that Vredenburg established the age of the Kama clays. As will be apparent these clays are the stratigraphical representatives of the clays which lie below the Prome sandstones of Murray Stuart east of Kama, and are not the Kama clay identified by either Murray Stuart or Vredenburg[1] at Kama. From Kama to the north-west the Prome sandstones lose a lot of their massive character and shales become more prominent in them. Northwards along the Irrawaddy they and the overlying alternating sandstones and shales are recognisable in that part of the Pyalo structure which occurs on the west bank of the Irrawaddy, and again as a sandy series underlying the Irrawaddian conglomerates two miles south of Thayetmyo town (19° 20′; 95° 11′).

The Okhmintaung ridge sandstones have a much greater development to the north-west and north than they have near Kyaukme at the latitude of Kama and besides forming the sandstones of the Monatkon and Okpon domes, are found overlying the shaly group containing coal seams and limestones of the north-eastern flank of the Lime Hill (19° 17′; 95° 8′) faulted anticline. The shaly group overlying them forms most of the Pegu outcrops west and west-north-west from Thayetmyo town but exposures in this latter area are very poor.

Bions suggested division of Pegu system in Eastern Thayetmyo.

Bion from work in Eastern Thayetmyo thought that the Pegu series might be sub-divided as follows :—

Upper Pegu Sandstones.

Kama Clays.

Middle Pegu Sandstones.

Kanhla Clays (Lucina beds, Dendrophyllia beds, Schizaster (Brissopsis) bed).

Lower Pegu Sandstones.

He was however unable to carry out such mapping in Western Thayetmyo where he described the exposures as 'contemptible' an opinion with which all geologists who have been over that area will I think cordially agree.

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[1] *Rec. Geol. Surv. Ind.*, LI, p. 237. (1921).

S. Rama Rau, correlation of Kama and Eastern Thayetmyo areas.

Mr. Sethu Rama Rau was not able to map the sub-divisions suggested by Bion in Eastern Thayetmyo although able to recognise them at various points. He suggested a correlation with Theobald's divisions as follows:—

Fossil-wood group .	Mogaung Sands . . .	Upper Pegu Sandstones.
Pegu Group .	Kama Clays . . .	Kama Clays.
	Prome Sandstones (B) .	Middle Pegu Sandstones.
	Prome Sandstones (A) .	Kanhla Clays.
	Sitsayan Shales . . .	Lower Pegu Sandstones.

This correlation I have now shown to be incorrect. It was undoubtedly occasioned by the Okhmintaung ridge series of sandstones being mistaken for the Prome Sandstones. The former must either have thinned out and disappeared to the south between Kama and Prome or else have become so poorly developed as to be regarded originally by Theobald as unworthy of note. Whether palæontologically the rocks described by Mr. Sethu Rama Rau in Eastern Thayetmyo as Kama clays correspond exactly with the upper part of the Sitsayan shale division of Theobald it is difficult to say. I did not find this shale series very fossiliferous in western Thayetmyo, and it is possible that Mr. Sethu Rama Rau's collections came from the top of the series in the passage beds to the sandy strata above, as seen by me east of Myohla. Mr. Sethu Rama Rau describes his 'Kama clays' of Eastern Thayetmyo as a series of bluish clays and sandy shales with occasional bands of sandstones and limestones, the abundant and beautiful collections of fossils being from sandy beds intercalated with clays. Similarly, east of Myohla, the collections made by me were from sandy beds intercalated by clays. In any case, the correlation with Eastern Thayetmyo arrived at lithologically by way of the Okhmintaung ridge series and the Western Outcrops is as given (*ante.* p. 147).

Theobald's inexact definition of Kama clays.

Many of the difficulties of the correlation of the Prome-Kama series of rocks with those found further north have undoubtedly been occasioned in the first place by Theobald's[1] very inexact definition of the Kama clays. Theobald never saw them overlying the Prome sandstones at Prome and he states that the relation of the clays which are 'fairly exhibited under the important town of

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[1] *Mem. Geol. Surv. Ind.*, X, p. 273, (1873).

Kama, 18 miles above Prome', with those seen in many spots east of the Irrawaddi 'may be generally detected at once by the numerous well preserved fossils they contain though in other respects they much resemble the unfossiliferous Sitsayan shales at the base of the group'. Theobald does not however give any specific determinations of the faunas collected to substantiate his correlations. Further, Theobald (p. 274), goes on to state that above this Kama shale occurs a very thick series of sandstones and shales which passes upwards into his 'Fossil-Wood Group'. Certainly no such series occurs above the Kama clays as identified by Murray Stuart[1] at Prome or Kama or by Vredenburg[2] at Kama (*loc. cit.*). Murray Stuart shows the Kama clays immediately underlying Theobald's Fossil-Wood Group at both Prome and Kama; he has left unmapped the intervening area in which they should presumably occur. In Plate 13, figure 1, I give a photograph of the clay band which underlies the town of Kama; this is obviously the band of clays to which Theobald alludes and which he mistakenly correlates with the fossiliferous blue clays of Eastern Thayetmyo.

Desirability of eliminating Theobald's nomenclature.

The desirability therefore of eliminating the nomenclature of Theobald is apparent on both lithological and palæontological grounds, lithologically owing to the development to the north of the intermittent Okhmintaung ridge sandstones in the Sitsayan shale division, and palæontologically owing to the Singu fauna being found to occur in the Okhmintaung ridge sandstones and the Kama fauna at the top of the shale division which underlies the Prome sandstones.

This of course has been done to a certain extent by Holland (see p. 144 *ante*) at Cotter's suggestion, only the Kama stage being now included in the palæontological sub-division of the Pegu system. Even this remnant is not very appropriately named owing to the clays from which Vredenburgs Kama faunas were collected being homotaxial with the alternating sequence at the base of the Prome sandstones and not with the clays exposed under the town of Kama. However, the Kama fauna is now so well known that it is preferable to retain the name Kama clays and to define it as the clay division immediately underlying the upper sandy series of the Pegu system in the Thayetmyo district.

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[1] *Rec. Geol. Surv. Ind.*, XXXVIII, Plate 23, (1909).
[2] *Rec. Geol. Surv. Ind.*, LI, p. 237, (1921).

Vredenburg's Pyalo and Akauktaung stages.

From the alternating sequence exposed at Kama and to the north-west the only recognisable fossils are according to Vredenburg[1] large specimens of *Ostrea latimarginata*, the species on which Vredenburg founded his Pyalo stage from a specimen collected at Pyalo from similar rocks, similarly situated with respect to the Irrawaddy-Pegu boundary.

Vredenburg's Akauktaung stage was founded on four species of *Ostrea* recorded by Stuart[2] from Henzada to the south, namely *O. Virleti*, *O. digitata*, *O. gingensis* and a form which Vredenburg[3] states is probably referable to *O. Crassicostata.* All four of these forms are according to Vredenburg (*ibid*) 'Among the characteristic fossils of the lower zone of the Mekran series of Baluchistan............ *Ostrea gingensis* is a form of wide stratigraphical range and occurs at all horizons of the Miocene. *Ostrea Virleti* and *O. digitata* are not known from any strata that can unhesitatingly be referred to an age as low as the Burdigalian'. In discussing the age of this fauna which he correlates with his Talar stage of the Mekran series and with the Tiji Lanang or alternatively, Odeng beds of Java, regarding the stage as Pontian or Vindobonian in age, Vredenburg assumes an unconformity below the Akauktaung stage and that Stuart's stratigraphy was correct. Cotter[4] has since given reasons for grouping the Akauktaungs with the Pegu system and for concluding that the unconformity was erroneously identified as such by Stuart. I have been over the various series in question at Kama and to the north-west and agree with Cotter. There is no unconformity in the upper part of the Pegu system in that area.

Doubtfulness of Vredenburg's Pyalo and Akauktaung stages in Thayetmyo.

Vredenburg[5] states that in the type locality of the Kama clays as identified by him (this should be about the top of the Kyaukkok sandstones in the Burma Oil Company nomenclature) 22 Siphonostomata have been securely identified of which three only *Clavatula munga*, *Drillia Kamaensis* and *Eburna lutosa* have not been recognised in the richly fossiliferous outcrops of Eastern Thayetmyo. He mentions that *Eburna lutosa* a species still living is known from the *Ostrea latimarginata* beds of the Pyalo anticline. Had the correct lithological correlations of Kama and Eastern Thayetmyo been known to Vredenburg one feels that he would never have introduced his Pyalo stage, but would have regarded the whole of the Miocene sequence in this area as of Kama age and extended the range of the stage from Aquitanian upwards to include at least the Burdigalian.

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[1] *Rec. Geol. Surv. Ind.*, LI, p. 238, (1921).

[2] *Rec. Geol. Surv. Ind.*, XLI, p. 245, (1911).

[3] *Rec. Geol. Surv. Ind.*, LI, p. 251, (1921).

[4] *Rec. Geol. Surv. Ind.*, LIV, p. 107, (1922

[5] *Rec. Geol. Surv. Ind.*, LI, p. 234, (1921).

In the geological map which accompanies this memoir, where I have endeavoured by hachuring to show the Upper Sandy Series and the Middle Sandstone Series of the Pegu system in areas south of latitude 19° 45′ that I have myself been over, the Upper Sandy Series probably corresponds to the combined Kyaukkok Sandstones and Obogon Alternations, and the Middle Sandstones Series to the Okhmintaung Sandstones of the Burma Oil Company nomenclature. It will be noted that the boundaries I have shown are dotted and therefore only approximate whilst in other places I have shown no boundaries at all. This is due to the impossibility owing to lateral variation of delineating a definite boundary on the 1″ scale maps on which I was working. The terms sandstones and shales used in describing the sub-divisions are only relative, and merely refer to the preponderance of one or other of these elements; the main sub-divisions I have included are, however, recognisable.

Southerly Sanding-up of the Burma Tertiary Gulf.

The chief characteristic of the sequence in the western outcrops, namely a sanding-up in a southerly direction due to an infilling of the main gulf by sediments from the north, and the consequent retreat of marine conditions southwards, has been mentioned by all previous authors (Dalton, Cotter, Stamp, Lepper) whilst Stamp[1] has emphasised the fact that this general thesis is 'complicated by intermittent earth movements which caused a periodical deepening of the gulf trough or a buckling of the floor and the temporary return of marine conditions northwards'. That there was buckling and a temporary return of marine conditions northwards, and not simply variation in the rate of subsidence bringing about conditions of non-conformity as speculated on by Cotter[2] is beyond doubt, as can be inferred from the consistency of the outcrops of the Yaw Shales and Padaung Clays. Overlaps by these latter sub-divisions are not noticeable from the south northwards, but from east to west overlap is a noticeable factor west of the main Tertiary sandstone range in the Minbu district, where the Padaung clays are found overlapping on to the lower part of the Pondaung Sandstones[1], and in the Pakokku District where Yaw Shales are found in proximity to strata of Ranikot age[2]. The chief characteristic is naturally more marked in the north of the area mapped where the Eocene and Pegu succession forms a simple monocline dipping east, and where the outcrops of the various sub-divisions run parallel with and close to what must have been the coast line of the Arakan Yoma mountain chain. It is not so apparent to the south where the folding is more intense and exposures of the various sub-divisions are obtained over sections from the coast line eastwards towards the centre of the gulf.

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[1] Geol-Mag. LXII, p. 516, (1925).

[2] *Journ. As. Soc. Beng.* N. S. XIV, No. 7, 414, (1918).

Southerly persistence of successively higer sandstone bands of Eocene and Pegu rocks.

Another characteristic of this western area is the manner in which successively higher sandstone sub-divisions of the Tertiary sequence successively attain a maximum and then peter out *en échelon* in a southerly direction. The Tilin Sandstones die out at latitude 20° 15′, the Pondaung Sandstones at latitude 20° 0′ and the Shwezetaw sandstones still further south. The Okhmintaung sandstones attain their maximum development at latitude 19° 15′ and apparently vanish before the latitude of Prome, whilst the Prome Sandstones attain their maximum development between Kama and .Prome. The quick change from massive sandstone to shale is also much more noticeable in this western area than it is to the east and probably the movements which occurred during Eocene and Pegu times were more accentuated in this area, to compensate for the concomitant rise of the Arakan Yomas. Indeed the evidence seems to show that for the greater part of the Tertiary epoch the Burma Tertiary gulf only occupied the western part of the area between the Shan Plateau and the Arakan Yoma. No Tertiary rocks older than Miocene have been discovered east of the line of vulcanicity which joins the Lower Chindwin volcanics with Mt. Popa and continues south along the eastern edge of the Yenangyaung basin to east of Zigon. East of this line the strata are all of a very shallow water facies, fossils being rare. Further to the east Irrawaddy sandstones overlie intrusive rocks along the edge of the Shan Plateau. These intrusive rocks have always been

Folding during Eocene and Pegu times.

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[1] Clegg: *Rec. Geol. Surv. Ind.*, LXVI, p. 250, (1933).
[2] Cotter: *Mem. Geol. Surv. Ind.*, 72, p. 38, (1938).

regarded as of Archaean age, but as I have shown elsewhere[1] it is possible that they may be of post-Jurassic age. I have also shown that Cretaceous rocks intimately connected with serpentines and rocks of diorite affinities similar to those found along the eastern flank of the Arakan Yoma and in the Andaman Isles, exist further north in Mongmit State, west of the main tectonic fold composed of metamorphosed and partially metamorphosed rocks which occurs along the Sino-Burmese boundary. With this fold, the folding and intrusions along the western edge of the Shan Plateau are intimately connected and a strong possibility exists that Cretaceous and older rocks occur at no great depth below the Upper Tertiary rocks of the eastern part of the Tertiary gulf and that it was not until post-Oligocene times that earth movements caused their submergence and an incursion of the sea from the west. In post-Oligocene times sedimentation appears to have been more continuous in this eastern area and whilst local unconformities are common the change from the marine Pegu to the fluviatile Irrawaddian rocks is gradual. In the Sagaing, Myingyan and Meiktila districts no definite boundary between the Pegu and Irrawaddian rocks can be mapped, and sedimentation appears to have been continuous during the period of unconformity represented by the Red Bed of Yenangyaung and the ferruginous conglomerates which, further west, mark the base of the Irrawaddy system.

The movements which occurred at the end of Pegu times seem to have been of a more intensive nature than those which had been going on before. So much so that the whole of the area now lying between the Arakan Yoma, the Andamans and the Nicobars on the west and the main land to the east, quickly became a land-locked estuary or lake as evinced by the fluviatile rocks of the Irrawaddy system which filled in the gulf and overlapped on to Eocene rocks of the Arakan Yomas and the Andaman and Nicobar islands, and on to metamorphosed and Cretaceous rocks to the east and north. It was not until post-Irrawaddian folding raised the northern part of Burma and depressed the southern that the sea overflowed once again into the Martaban basin and conditions were again attained similar to those of the Burma gulf in Eocene and Pegu times.

Structurally, the area described includes the south-western part of what may be described as the Yenangyaung basin which is

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[1] *Rec. Geol. Surv. Ind.*, 71, p. 376, (1937).

Structure.

the southern of the two basins comprising the western part of the main Tertiary geo-syncline of Burma. It is only in the western part of the Burma Tertiary geo-syncline that oil has as yet been discovered in economic quantity and that mainly in the southern basin. The northern or Upper Chindwin basin contains only the Indaw oil-field whilst the southern or Yenangyaung contains the well known petroliferous anticlines of Yenangyat, Singu, Yenangyaung, and Minbu, the subsidiary oilfields of Yenaman and Padaukpin and the gas-field of Pyaye.

Yenangyaung Basin.

The closing-in of this Yenangyaung basin owing to more intensive folding to the south is well brought out in the section (Plate XVI). At the latitude of Yenangyaung (20° 30′) the distance between the watershed of the Arakan Yoma and the metamorphosed rocks of the edge of the Shan Plateau reaches practically its maximum; at the latitude of Kama (19° 0′) it reaches its minimum. As Irrawaddian rocks are folded in with rocks of the Pegu system in the south, post-Irrawaddian folding has obviously been responsible for the Yenangyaung basin which has been caused by a differential easterly movement of the Arakan Yomas. This differential movement has resulted in the arc, convex to the east, which the south part of the range exhibits.

Main structure; Western Outcrops.

The main structure in the western outcrops is the fold fault of the Nwamadaung range. In the north (Plate XVI, Section along A-B) this fault duplicates the Upper Eocene and basal Pegu succession in the Pazawbya syncline to the west. Further south where the Man *chaung* crosses the range a similar structure (Section along C-D) occurs and west of the fault foraminiferal limestones of Padaung clay age are found overlapping directly on to basal Pondaung sandstones. A few miles further south the characteristic calcareous fossiliferous horizon of the Yaw stage at the top of the Eocene, is duplicated by a similar fault, but the massive sandstones which occur below it in the eastern exposure cannot be recognised as such underlying it to the west. Further to the south the faulting has not been so severe and an anticlinal structure, albeit very much broken, can be recognised. On the western flank of this anticline, basal Pegu strata occur in a string of basins in the Shandatkyi reserved forest and along the Pani *chaung* to the south. In this area a certain amount of minor faulting also occurs.

North of Kyaukkyi the general anticlinal structure of the Nwamadaung range pitches out steeply, and a bay of Pegu strata tongues up the Pani *chaung* to the north-west. On the western flank of this bay another broken anticline of Eocene strata occurs *en échelon* with that north of Kyaukkyi, and Eocene rocks are repeated in the syncline of the Thambula reserved forest to the west. To the south this structure is sharply modified by a cross-fault north of Shwenattaung Pagoda, and in the syncline which persists across the fault to the south, only Pegu rocks are present, the Eocene strata having been faulted back to the west. In these Pegu rocks another anticline faulted on the west develops south of the Mindon *chaung* but pitches out to the south before it reaches the Made *chaung*.

More intensive folding of Pegu rocks south of Minhla.

East of the western outcrops in the northern area, the strata form a simple monocline, although east of the Irrawaddy outside the area mapped, Pegu rocks are exposed in the gentle anticline of Yenangyaung. Further to the south (latitude 20°) the Minbu anticline rises steeply from below Irrawaddy sandstones. Thereafter, to the south, folding becomes much more intense, and the whole of the Pegu rocks lying west of the Irrawaddy river between Thayetmyo and Minhla, are folded into a series of anticlines and synclines.

Asymmetric folding on the flanks of the Yenangyaung Basin.

Further south, a succession of five parallel anticlines arranged *en échelon* occurs in the western part of the Thayetmyo district between Sinde (19° 26′ ; 95° 10′) and Gyobin (19° 2′ ; 94° 54′) Of these, strike faulting occurs along the western flanks of those of Leptanzeik (19° 22′ ; 95° 12′) the Lime Hill (19 17′ ; 95° 9′) Natmidauk (19° 10′ ; 95 4′) and Wetchan Taung (19° 8′ ; 94° 57′) over-folding being to the west. In the north-west part of the Yenangyaung basin outside the area mapped, strike faulting combined with overfolding to the west also occurs along the western flank of the anticlines of the western outcrops, namely, those of Ngahlaingdwin and Leya. On the north-eastern flank of the basin however strike faulting occurs along the eastern flank of the anticlines (Yenangyat, Singu, Gwegyo, Ngashandaung) and the overfolding is to the east. In the centre of the basin the Yenangyaung anticline is almost symmetrical. This arrangement of the hades of the planes of flanking folds towards the central axis of the Yenangyaung geo-synclinal basin is surely not pure co-incidence; possibly it may be regarded as evidence in favour of the greater thickness of sediments which apparently occur in the western basin. The folding in the western area appears to be of a deeper as contrasted with a shallow type of folding found to the east and the result is certainly what one would expect if the Tertiary rocks to the east originally consisted of only the uppermost Tertiaries overlying partially metamorphosed rocks of Cretaceous age and the basin to the west a full suite of Tertiary rocks of great thickness.

Cotter in Memoirs Geological Survey of India, 72, Pt. 1, (1938) has given a description and critical examination of all the faunas comprising the lithological divisions of the Eocene, Lower Pegu and Irrawaddian rocks and of the palæontological stages established by Vredenburg of the Pegu rocks, and the reader is referred to that publication for fuller details than are contained in Holland's, 'Terminology' (quoted above), should he not wish to consult the original references given.

CHAPTER IV.—DETAILED DESCRIPTION OF ROCKS : THE AXIALS.

Theobald's definition of term 'Axial'.

The term Axial was first applied by Theobald[1] to a group of rocks which 'seemed everywhere to comprise the central region or axis of the range (Arakan Yoma), but the relations of which to the newer or nummulitic group were not there very clearly displayed, partly from the nature of the ground and partly from the character of the beds which, though of great thickness, were very deficient in salient points for arrangement and sub-division'. This series had previously been termed 'Hill Rocks' by W. T. Blanford who expressed an opinion founded on an examination of the Bassein district that this series were 'as likely as not' altered Nummulitic strata although no fossils had been found in them. A few years later Theobald visited a portion of the ground surveyed by Blanford but found himself 'unable cordially to assent' to this view of Blanford and preferred to leave the question open.

The 'Hill Rocks' of Blanford.

Theobald's first Axial-Nummulitic boundary in Minbu and Thayetmyo.

Later when Theobald[2] commenced work on the frontier (latitude 19° 30′) in 1869-70 among the Axials as restricted by him, which thereabouts contrast with the Nummulitic group of the plains to the east, he thought he recognised 'a confirmation of the view to which he had always inclined, namely, the distinctness, geologically speaking, of the altered and unaltered rocks which had proved so puzzling in Bassein'. In following southwards the boundary of the Axial group and the Nummulitics, Theobald supposed that he was holding the clue to the true relations of the rocks in Bassein. At first all went well, but hardly had Theobald got south of the Prome district, when he began to feel less satisfied with his Axial-Nummulitic boundary, and by the time he reached the Bassein district was convinced that the boundary he was then following, was not a true stratigraphical one, but merely one dividing altered from unaltered rocks of the same group; this boundary was becoming more and more vague towards the south, where Blanford had originally remarked that 'no separation was possible between these often dissimilar but really geologically identical groups (*i.e.*, Nummulitics and Hill Rocks)'. Theobald now became convinced of Blanford's view and, as corroborative evidence, was able to find numerous small nummulites in a limestone in Pyinnea *chaung*, ten miles west of the Bassein river within the area of the 'Hill Rocks'; he then searched for the point where in following down the line of altered rocks he had got 'shunted off the Axials on to the Nummulitics'. This he ascertained to be on Thanni *chaung*, 47 miles, as the crow flies, due south of the frontier, and a little above the latitude of Prome.

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[1] *Rec. Geol. Surv. Ind.*, Vol. IV, Pt. 2, p. 33, (1871).

[2] *Rec. Geol. Surv. Ind.*, Vol. V, Pt. 3, p. 80, (1872).

Theobald accepts Blanford's view of Hill Rocks.

Here Theobald found that his Upper Axial beds, which consisted of freckled grits, shales, sandstones and conglomerates disappeared abruptly, as, although up Thebyu *chaung*, a small tributary of Thanni *chaung*, he found the characteristic Axial limestone, below the junction of this tributary and the main *chaung* he could 'confidently refer the shale seen to the Nummulitic group'. Above the junction there was great alteration and disturbance of the beds; 'harsh indurated sandstones, vertical and much shattered and disturbed occur and above this spot sandstones and shales of the ordinary kind met with among the "Hill Rocks" to the south'. Theobald goes on to say that 'for any direct evidence to the contrary these rocks above the junction are quite such as would identify them with the group of similar character underlying the upper or typical Axials'.

Theobald: Thanni *chaung* section.

In speaking of the whole of this Thanni *chaung* section, Theobald[1] states, that it is a better and more sharply defined junction than usual, of the altered or 'Hill Rocks' with the unaltered Nummulitics, and at the time of his first visit, he had no doubt of its being the faulted boundary of the Axials and Nummulitics instead of merely 'the boundary of that peculiar metamorphism which characterises the Hill Rocks and which the further we go south seems more and more capriciously and irregularly developed'. On the subject of the Lower Axials at this point Theobald says

> **'Of the lower Axials now that all the Hill Rocks to the south are separated from them we know very little. The country occupied by them being, without any figure of speech, most impracticable. From the point near the Thanni *chaung*, where the group terminates, the boundary recedes to the westwards along the**

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[1] *Rec. Geol. Surv. Ind.*, Vol. V, Pt. 3, p. 81, (1872).

watershed separating the Thanni *chaung* from the Muday (Made) *chaung* to the north. This is indicated in the map by a dividing range, which gives a very inaccurate conception of the physical aspect of the country, though it may, very probably, correctly enough mark the actual watershed. Nattaung, a conical hill capped with serpentine is situated between the Thanni and Muday streams at almost the extremity of the Axial area............ From the summit a fine view is obtained of the ground intervening between it and the main Yoma range, but which being intersected by no considerable stream, totally uninhabited and covered with virgin forest *is quite impossible to explore ;* and it is not till the western side of the Arakan range and the Akyab district comes under survey that more details of the Axial group can be looked for ; and even then the difficulties presented by the wild forestclad and uninhabited nature of the country in question, will for many years act as a complete bar to anything like a full and satisfactory examination of the ground .'

Inaccessible nature of country west of Nattaung.

Theobald : Introduction of term Negrais for 'Hill Rocks' of Blanford.

For these 'Hill Rocks' which stretch from south of Thanni *chaung* to Cape Negrais and along the Arakan coast, Theobald[1] applied the term Negrais, this term being defined as embracing all the rocks met with in the Pegu and Arakan districts older than the Nummulitic and newer than the Triassic; he mentioned that it was by no means certain that some of the rocks included in this group were not, as he had at first surmised, of Eocene age, and highly probable that it also included rocks of Cretaceous age. Theobald now restricted the term Axial to what he thought was the older group of the western Thayetmyo and Prome districts, which he believed to be of Triassic age. Later Nœtling[2] expressed the opinion that Theobald's Negrais rocks were probably metamorphosed Eocene beds and that his Triassic rocks might be either the lowest Tertiary or topmost Cretaceous strata, the Triassic age assigned being on the strength of a misinterpreted fossil; Nœtling introduced the term Chin Division for these altered rocks of the Arakan Yoma. It may be mentioned, however, that Nœtling did not visit any areas occupied by the so-called Axial rocks (*sensu lato*) of Theobald.

Cotter[3] has given a very full review of the palæontological evidence on which Theobald's groups are based together with evidence subsequently obtained. In his conclusions Cotter states—

'(*a*) that the distinction between the Negrais and Axial rocks is very doubtful; (*b*) that both are complex groups comprising rocks of different ages;

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[1] *Mem. Geol. Surv. Ind.*, Vol. X, p. 299, (1873).
[2] *Rec. Geol. Surv. Ind.*, Vol. XXVIII, p. 61, (1895).
[3] *Mem. Geol. Surv. Ind.*, Vol. 72, p. 21, (1938).

(c) that the strip of Eocene rocks mapped in the central Yoma area[1] is probably a mistake; its existence is certainly very questionable[2] and (d) that Cretaceous rocks of Albian or Turonian age occur at Mai-i on the coast and in Ramri island on the same strike, but there is no justification for marking the Cretaceous belt as extending so far inland as Theobald has done.'

In summing up the age of the Axials, Cotter mentions:—

Cotter: Age of Axials.

'(1) The presence of conglomerates of age later than the serpentine intrusions; these conglomerates are later than the Axials but folded into them. They are unconformable to the Axials in North Minbu.

(2) An infold of Danian beds (*Cardita beaumonti*) in the Thayetmyo Axials, associated with conglomerates.

(3) Beds of Upper Cretaceous age resting upon Axials in Henzada and Pakokku.

(4) Serpentine and peridote intrusions of pre-Danian age from the Andaman islands north through the Yoma to the Naga hills and the Disangs of Assam.

(5) The occurrence of undoubted Triassic fossils in Thayetmyo; *Globigerina* limestone of unknown age in North Minbu, plant remains, and an unidentified ammonite in Assam.

(6) An immense extent of monotonous alternating successions of slaty shale and fine grained sandstones entirely unfossiliferous, except for the occurrences mentioned above.'

Cotter concluded that 'the Axials are probably a complex of rocks of varying age, but it is possible that the great bulk of them may be pre-Cambrian or perhaps comparable in age to such groups as the Simla slates and the Jaunsar series. The few fossiliferous beds seen may represent infolds of rocks of later age, including Triassic strata'.

South end of Arakan range: Rocks not older than Cretaceous.

With these conclusions of Cotter I am not in general agreement. I think there is little doubt that at the south end of the Arakan range the rocks are probably all of Eocene or Cretaceous age. I certainly do not believe that Triassic strata have been proved to occur. According to Theobald (*ibid* p. 135) a few specimens (Triassic) were obtained from the crest of a low hill, one and a half miles south-west of Thabyegaing which Stoliczka identified as *Halobia Lommeli*. In the same vicinity, the limestone is reported by Theobald to be of various tints of pink and yellow and occasionally converted into a white crystalline rock. According to Tipper[1] the occurrence of these Triassic rocks is noticed in the first edition of the Manual of the Geology of India, Vol. II, pp. 710, 711, but in the second edition (p. 149 footnote) it is stated that the fossil was wrongly identified and that the rocks are not Triassic but Tertiary. The same view is expressed in the Annual Report of the Geological Survey of India, 1893, page 9. In the annual report for 1900-01, pp. 19, 20, the view is expressed that if Triassic rocks do occur they are probably as Klippen in newer deposits.

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[1] *See* map: *Mem. Geol. Surv. Ind.*, Vol. X, (1873).

[2] This is obvious from the excerpt I have given (*ante* p. 177) from which it appears that Theobald never went west of Nattaung (18° 57′ : 94° 58′) on the eastern side of that section of the Arakan Yoma.

Tipper states that a search in the Museum brought to light one of Theobald's original specimens, 'a hard black limestone with numerous lamellibranch casts and fragments' and it was development of one of these casts that showed that the specimen was an *Halobia* and that in the same block were some *Monotis* like shells and an *Avicula*.

Theobald never mentions any 'hard black limestones' and all Datta's specimens from the area were grey, but, in the same note, Tipper most ingenuously mentions another collection of Triassic rocks from Burma, which had so far escaped notice, and consisted of a series of 'hard black limestone blocks' crowded with extremely well preserved specimens of *Halobia* allied to the *Halobia* of the Arakan Yoma, and *Monotis*. The label attached to the latter read 'Sent to Mr. Theobald by Mr. D. O'Riley from Karennee, Aug. 1864'. There seems little doubt in my mind that the specimens examined by Mr. Tipper were misplaced by Theobald from the latter collection and that Triassic rocks have so far not been proved in the Arrakan Yoma. This is not the only instance of the mixing up of specimens by Theobald, as specimens registered in the Geological Survey catalogue as being from the Lime-Hill, south of Thayetmyo, were found to contain three species of Khirthar *Orthophragminæ*.[2] Diligent search since by numerous geologists in the locality noted has only produced Oligocene *Lepidocyclinæ*, whilst to the west of the Thayetmyo district the three species of Khirthar *Orthophragminæ* purporting to come from the Lime-Hill are very common indeed.

In the north of the Minbu district and in Pakokku the degree of metamorphism of the Axials is more intense than to the south, and in places where I saw them, I certainly thought that Chaung-Magyi rocks were included in the series. However, outside typical areas where Chaung-Magyi rocks are overlain by fossiliferous Ordovician strata, the identification of the Chaung-Magyi series is always very doubtful, and ever since its inception the name has been utilised by most Burma geologists for any series of metamorphosed or submetamorphosed rocks of slaty character, which could not be specifically correlated by direct mapping or by palæontological evidence.

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[1] *Rec. Geol. Surv. Ind.*, Vol. XXXIV, p. 134, (1906).

[2] Cotter : *Rec. Geol. Surv. Ind.*, Vol. XLI, p. 323, (1912).

Mongmit State: Rocks similar to Axials.

Recently, (1936), I had occasion to traverse across the Mongmit State to the second defile of the Irrawaddy just below Bhamo. On the route followed, granitic intrusions were common and also various indurated rocks of slate-like character which, for want of a better name, I classed as Chaung-Magyis. Later I found a highly folded and faulted but less metamorphosed series with what one must presume were intercalated limestones. I tentatively placed these limestones as Palæozoic owing to their massive character. Later, in a limestone in a topographically lower series which appeared to underlie the massive limestones, Cretaceous foraminifera were found to occur. In the field I had placed the sandy sections of this latter series as lying on an eroded surface of limestone and so had correlated their limestone intercalations with the massive limestones. In my field note-book I find that I had remarked on the similarity of this less metamorphosed series, to rocks seen at the foot of the Arakan Yoma range in the north-west Minbu and south-east Pakokku districts whose age I had been unable to determine but from whose character I had included in the Axials of Theobald.

Reversion to Theobald's original term—Axials.

In the area under description I only saw what I took to be Axial rocks in Sheets 84 L/3, 84 L/7 and 85 I/16. So far as I was concerned the term 'Axial' to me meant the Hill-Rocks of Blanford, the original Axials of Theobald and the Chin Shales of Nœtling. Owing to Theobald's very doubtful distinction between Negrais and Axial rocks a reversion to this original nomenclature was inevitable. The term Axial is much better than Chin Shales for this series as so many different kinds and types of rock are included in it, and so far as is known, these rocks of doubtful age extend from the Andaman Islands through Cape Negrais to Assam.

Axials west of Sidoktaya.

West of Sidoktaya (20° 27′; 94° 14′ 30″) the Axials consist of shale, schistose sandstones, schists and lavas. The occurrence of the lavas lying in big blocks upon sandstones recall the structure of pillow lavas. A conglomerate which has been taken as the base of the Eocene in this area is seen two miles west by south of Sidoktaya on the Sidoktaya-Kanywa tract. It is a tough quartzitic conglomerate, the pebbles varying in size from sand grains up to one inch in diameter and, rarely, up to six inches. Under the microscope the pebbles are seen to consist mostly of mosaics of quartz. Strained polarisation is common in this quartz, the larger pebbles showing the greater strain. Pebbles of microcrystalline quartz are also present in small quantity and a ferruginous cement forms the groundmass.

Westwards from this conglomerate on the Kanywa track (20° 25′ 30″; 94° 10′ 30″) the Axials show fine-grained contorted shales with some secondary silica; these are exposed a quarter of a mile west of the conglomerate, whilst west of Kanywa, (20° 25′ 30″; 94° 10′ 30″) along the Palet trail little can be seen but schist and phyllite detritus. The trail is overgrown by creepers and on the watershed there is a thick undergrowth and carpet of rotting vegetation. Just above the village of Kanywa amygdaloidal volcanic rocks occur but the valley below is composed of slaty schist. In the Palaung *chaung* three miles north-west by west of Sidoktaya the rocks of the Axial boundary are all very much crushed and contorted. In the series above the basal conglomerate the contorted rocks vary from fine-grained sandstone to coarse grits and conglomerates. In Sheet 84 L/7 to the south, the conglomerate which has been taken as the base of the Eocene, coincides with the reserved forest boundary one mile south-west of Thetle (20° 22′ 30″; 94° 16′); both above and below it the strata are all very contorted; above they consist of lavas, shales and sandstones and below of crystalline limestones and other indurated rocks. Just inside the Axial boundary the head-waters of the Yebauk *chaung* have been captured by the tributary stream which flows south-east to join the Thaga *chaung* immediately east of the Munzaw (20° 21′; 94° 17′). Crystalline limestone occurs on Hill 1136 (20° 19′ 30″; 94° 17′) one mile south by east of Atet Munzaw (20° 20′ 30″; 94° 17′) whilst on Thaga *chaung* three quarters of a mile to the south-west the basal conglomerate dips 40° E. 5° N; it contains pebbles of quartzite, slate and schist, generally about one inch in diameter. To the west it lies unconformably and probably with a slightly faulted boundary on shales and lavas. The shales are very homogeneous, contain limy concretions and break down on weathering into flakes and splinters; the lava is amygdaloidal and very much altered. Further to the west occur ashes, agglomerates with lava bombs up to six inches in diameter and altered lavas. Above the boundary the rocks consist of alternating sandstones, shales, and ashes all very much broken and contorted and approximating to vertical. One mile south by east of Munzaw an Eocene foraminiferal limestone occurs.

Hayden: Axials west of Hpa-Aing and Ngape.

In Sheet 84 L/8 conglomerates characterise the lower Eocene rocks which overlie the serpentine-intruded Axials. These Axials were traversed by Sir Henry Hayden[1] when reporting on the steatite mines of the Minbu district and I give an extract from his paper which deals with these boundary rocks, firstly, west of Ngape (20° 4′ 30″; 94° 28′) to the south, and then with those west of Hpa-Aing (20° 15′ 5″; 94° 20′).

Geology.

"As the road approaches Ngape, the sandstones become unfossiliferous and between that place and Shauktaung (19° 58′; 94° 30′ 30″), the beds appear to contain no recognisable organic remains. At about half a mile west of Shauktaung the sandstones are underlain by thick beds of very finely laminated dark shale with occasional carbonaceous bands. In these shales occur at first narrow bands of sandstone, and beneath these a thick bed of grey limestone, with nummulites in places: as a rule, however, in this neighbourhood, the limestones have been altered to such an extent by outbursts of a dark green serpentine, that the fossils are not recognisable. Beneath these limestones come—

(1) a bed of very dark purple schist, containing some limestone bands, and succeeded by

(2) an immense thickness of green and purple shales, containing enormous quantities of vein-quartz. These rocks (1 and 2) are presumably the "Chin shales" of Dr. Noetling.[2]

In the neighbourhood of Shauktaung, the tertiary beds dip to the east at an angle of 40°, and form parallel ranges of low hills running north and south and bordering the Arakan Yoma. These rocks show no signs of alteration. As soon, however, as the "Chin shales" appear, a remarkable change is noticed; the rocks then become folded, crushed and faulted, and in this condition form the greater part of the Arakan Yoma. At about 1½ miles west of Shauktaung the "Chin shales" first appear and continue without interruption to Won. About 1¼ miles west of Won they are well seen in the steep, precipitous sides of the Mankyaung. Here also occur numerous dykes and intrusions of a grey dolerite, which is seen in great masses in the "Chin shales". Numerous boulders of dark green serpentine and a somewhat fine-grained green gabbro occur in the stream-bed. Two and a half miles west of Senlan are found large quantities of the above serpentine. The rock has been much crushed and in places strongly resembles the "Chin shales". It contains numerous veins of steatite, and it is here that the new mines already described have been opened.

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[1] *Rec. Geol. Surv. Ind.*, Vol. XXIX, pp. 74-76, (1896).

[2] *Rec. Geol. Surv. Ind.*, Vol. XXVIII, Pt. 2, p. 62, (1895).

The general strike of the rocks being north and south, the same beds are met with in the journey from Hpa-Aing to the older quarries. A few points of difference are, however, noticeable. One of these is the much smaller quantity of vein-quartz found in the "Chin shales". Another very interesting feature of the rocks here is formed by numerous strings of quartzite pebbles and boulders enclosed in these shales: these enclosures are of all sizes, and range from blocks weighing several tons down to fragments an inch or so in length. They appear to lie along the cleavage planes, with their long axes in the direction of strike of the cleavage. The enclosures are well seen in the Kyikyaung, at the halting place reached at the end of the third day's march from Hpa-Aing. Here, too, a band of quartzite is seen interbedded with the shales. The appearance of the shales and their enclosures so exactly resembles that of the quartzite pebbles and boulders seen in the Cambrian slates on the peninsula of Howth, near Dublin, that one is constrained to assume a similarity in their mode of origin.'

This latter phenomenon has been described by Prof. Sollas, who writes—

'on the north side of Howth one may observe how great blocks of quartzite have been squeezed out from their bed during folding and carried into a stream of flowing slate, to form veritable intratelluric erratics. Near the nose of Howth whole trains of such erratics may be seen; these, no doubt, stand in connection with an important plane of shearing along the middle limb of an overfold........ The whole terrain seems here to have been thrown into a state of intestine movement flowing up, down and sideways, and even whirling round about'.[1] 'The boulders of quartzite are in some cases so large as to preclude the probability of their having been waterborne, while at the same time their exact resemblance to the neighbouring bed of quartzite is strong evidence in favour of their having been derived from it.'

The amount of pressure to which these shales have been subjected, though probably not so great as that which the Howth rocks have repeatedly undergone since Cambrian times, has, nevertheless, been sufficient to elevate the great mountains of the Arrakan Yoma, and to fold and contort the shales to a vast extent. The cleavage and bedding of the shales appear to correspond and, where not vertical, the prevailing dip is at a high angle (80° and over) to east or west. Everywhere overfolds, faults and broken-backed anticlinals are seen, and it is almost impossible to estimate even roughly the true thickness of these beds which extend, at any rate in the neighbourhood of Shauktaung and Won, over more than six miles of country. Nor does the possibility of the discovery of fossils in beds which have been so crushed seem to be anything but exceedingly remote."

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[1] Proc. Geologist's Assoc., Vol. XIII, Pt. 4, (1893). The Geology of Dublin and its neighbourhood.

Cotter describes the Axial rocks of the same area in his progress report for 1912-13 as follows:—

Cotter: Axials of Sheet 84 L: 8.

Chin Shales.

"The name Chin Shales has been given by Noetling to the series underlying the Eocene. The term "shales" is not well chosen. Certainly shales are to be found in this series, but the usual types of rock are quartz-schist, hornstone, talcose slate, slate; shale is not common and is often carbonaceous.

The Chin series are full of veins of serpentine or steatite its alteration-product. The Chin series can best be studied by wading up-stream up the small chaungs which run from the divide. It is not of much advantage to climb up the hills, since the exposures are poor. I shall describe the stream sections first.

Stream sections in the Yomah.

Man River.—I could not get up the river at the time of my visit since the fords were over six feet deep, and the Burmans at Ngape would not undertake to go. The footpath to Thitkut was ascended for a short distance, but no exposures *in situ* were seen, and no serpentine. Loose pieces of sandstone were found on the surface of the ground, but these might belong equally well to either the Lower Eocene or the Chin series. I believe the boundary of the two series to be about five furlongs S. W. of Minlwin village (20° 4′ : 94° 25′) in this section, but cannot draw it exactly.

Ugin chaung.—Proceeding westward from Shitku village (20° 8′ : 99° 24′): Lower Eocene conglomerates are passed, and then serpentine appears, but the junction of the Lower Eocene and the serpentine is in a band about one mile thick, and apparently solid. The Ugin river forms a deep gorge westward of the serpentine, grey schistose slate is exposed in which are numerous quartz-veins.

Pazi chaung.—About five furlongs west of Ngayanchaung (20° 9′ : 94° 23′) village altered serpentine full of calcite veins is seen; further west the serpentine is more fresh and solid.

Schists are exposed in the river section to the west of this. Near the intersected point marked 940 serpentine altering into calcite is seen. The rock in parts is almost entirely calcite, and is of a pale buff colour; its surface weathers in a curious network.

West of this, stratified rocks, mainly quartzitic sandstones are seen, and still further west a bed of massive serpentine about 15 yards in thickness; and westward beyond this a long section of the usual schistose rocks of the Chin series, filled with numerous quartz-veins.

Don chaung.—Compared with the Pazi *chaung* section, the rocks of the Don *chaung* are a very much less altered; sandstones and shales being seen in several localities. There are no veins of serpentine here; probably this partly accounts for the unaltered appearance of the rocks.

Especially noticeable in this section is the intense amount of disturbance to which the rocks have been subjected. They are broken, contorted, and dip irregularly in all directions.

Zi chaung.—In this section after passing the Lower Eocene conglomerates, nothing but Chin Series is seen. These are here hard sandstones, slaty black shales, and quartz-schists with vein quartz. About 1½ miles from the boundary massive serpentine is seen.

Hill-Sections.

Thetkegyin footpath.—Along the path to Thetkegyin (20° 11′; 94° 16′) sandstones of Lower Eocene age occur until about ½ mile from Sitsayan village (20° 13′; 94° 19′) where serpentine is first seen. The serpentine belt is here about ⅛ mile thick. Westward shales and schists are seen, but exposures are very rare. At Thetkegyin village is an exposure of black shaly graphite with quartz-veins. The road to the Steatite Mines (visited January 1912) from Thetkegyin descends to the Kyi *chaung* where the rocks are disturbed but dip usually to about 30° S. of W. at angles of about 80°. The rocks exposed here are of "horn-stone" type.

From the Kyi *chaung* the path ascends to the Yomah divide. Talc-schist and possibly Kyanite schist occurs. Quartzite is seen in places. Vein quartz also. There are exposures of quartzitic sandstone with vein quartz at Thitmyitgyi (20° 11′; 94° 4′ 30″) and Thitmyitkale (20° 12′; 94° 3′ 30″) camping grounds on the top of the Yomah. The dip at Thitmyitkale was 65° to 10° S. of W.

The mines themselves are in exactly the same condition as when they were visited by Mr. Hayden in 1895, and do not require further description. A specimen of serpentine partly altered into steatite was collected.

Steatite also occurs on the spur of the Yomah between the Zi and the Don *chaungs*.

Structure of the Yomah.

The Yomahs are clearly fan-structured. The dips are very irregular owing to the contortion, but broadly speaking they are generally close to the vertical and the strike is 10°-30° W. of N. Fold-faults must of course abound, and the structure must be regarded as the fan-structure of the isoclinal. It is obvious that rocks of very different ages are packed together in one metamorphosed complex. Probably this complex will never be unravelled. In the absence of fossils it is impossible to separate the series. Some geologists have regarded the Yomahs as Tertiary in age; others as Cretaceous. We know that both Cretaceous and Triassic occur; it is also quite possible and even probable that Tertiary rocks are also folded into the Yomahs. Some of the shales and sandstones have an appearance like that of the Pegu series, but they are unfossiliferous.

Axials : Unfossiliferous nature of.

Although fossils have been found in three localities by Theobald, two of those were from stream-beds where the specimen was not *in situ*. Their occurrence is certainly very rare".

The following note of Bion's regarding Theobald's boundary west of Mindon (19° 22′; 94° 46′) was taken from his field note-book for 1915 :—

Bion : Axials west of Mindon.

"Theobald draws the upper boundary of the Axials between Taunglat (19° 22′; 94° 42′) and Tama auk (19° 22′; 94° 43′). I examined the section between these villages and there is no doubt that there is no sort of break here. The Axials pass up by insensible gradations into the Nummulitics. Nevertheless Theobald's 'Axials' are worth separating off as a lithological zone marking special conditions of deposition. They are characterised throughout by grits, ashes and shales which are often porcellanous. The grits rarely attain the characters of conglomerates but are often coarse and they occur right through the group. Most of them are largely made of ash but a striking feature is the presence of pellets and lumps of clay derived from some pre-existing clay bed. They cannot therefore have been deposited far from their source of origin. The sandstones commonly weather into spheroids exactly like basalt and in the field are at first sight just like lavas. The shales are most peculiar and quite unique. A common type is a dark hardened clay which shivers into small fragments under the hammer. Peculiar hard white porcellanous beds are also common."

Kadaing area.

From one mile south of Kadaing (19° 22′ 30″; 94° 38′) Bion collected a cast of a *Schizaster*, and a doubtful *Cardita*, and from the Pyet *chaung* just over two and a half miles north by west of Kadaing some loose *Lithothamnium* limestone.

In the Pazin *chaung* which debouches into the Mindon, Mu or Mahton *chaung* three miles north-west of Kadaing, Bion describes the following section which dips 30° west from a point 100 yards below the confluence of the tributary, Kangok *chaung*:—

4. White sandstone.
3. Clays with fossils—small *Corbulas*, gastropod casts, ? *Cardita*, ? small ammonite.
2. Limestone and calcareous conglomerate with *Lithothamnium*.
1. Massive conglomerates, grits and sandstones.

According to Bion, from the aforesaid confluence east up Kangok *chaung* the dip steepens rapidly to 70° west and then about a quarter of a mile east of the stream junction a faulted anticlinal crest can be seen in the stream. Above the crest to the east the dip changes to 50° south. Blocks of the same *Lithothamnium* limestone are seen in the stream and it is clear that the limestone is repeated on either side of the faulted anticline.

Pyaung Area.

Further south between Pyaung (19° 20′; 94° 41′) and the Yin *chaung*, sandstones, grits and conglomerates were noted by Bion striking north by west and dipping at steep angles. For about one and a half miles west of Tanlebin (19° 19′; 94° 42′) the dip is to the west by south at from 70° to 80°. At the right angle bend in the Padin *chaung* a quarter of a mile south of Pt. 995 (19° 19′; 94° 41″) the dip is vertical, where some 200 feet of limestone, calcareous conglomerate, calcareous sandstone and calcareous shale full of *Lithothamnium* cuts across the *chaung*. Bion notes that this is the limestone found by Theobald, but that the latter must have seen it on the summit of Hill

995 where it is quarried on a small scale for local use. The section in the *chaung* is a good one and shows that the limestone is very irregular and fully justifies Theobald's description of it as a 'rubbly limestone conglomerate'. The lime is, according to Bion, due solely to algal growths and nodules of limestone shewing algae on breaking across, occur in shale, sandstone, and conglomerate, indiscriminately. Here and there the nodules are numerous enough to have become compacted together into a sort of rubbly limestone.

Yin Chaung Sequence.

In the Yin *chaung*, to the west, clay shales dip east by north at steep angles although but a quarter mile up the tributary stream from the confluence south of Pt. 643 (19° 18′; 94° 40′) Bion noted 'Kanpetlet schists faulted as usual' against the conglomeratic and ashy series. Bion notes that the separation of these two series is very simple owing to the older schists being violently contorted, crumpled and 'teased out' whereas the younger beds are merely slightly cleaved. The 'Kanpetlet schists' in this area are mostly phyllites, bluish and blackish, with quartzite bands 'teased out' among them and according to Bion closely resemble the Morte slates of Devon. Bion noted chromite from a segregation in the serpentine which outcrops in the Mu *chaung* three miles north-east of Kadaing.

CHAPTER V.—DETAILED DESCRIPTION OF ROCKS: THE AXIALS—(*Continued*).

Theobald's descriptions.

Apart from the exceptions given in the last chapter, south of latitude 19° 30′, the Axial rocks have only been examined by Theobald, although I have been up to the boundary in Made *chaung*. As Theobald's memoir is out of print I have included his observations on this area in detail. They are as follows[1] :–

'The best characterised portion of this group (Axial) is what I have designated the upper Axials in my sketch of this group in the Records of the Geological Survey (Vol. IV, for 1871, page 36). At the base of this upper division occur the only two beds wherein I have detected fossils, though I am sanguine of future researches in this group revealing a richer fauna, when a wider area of these beds comes under observation. This upper group extends from the frontier down to the point where the Axials disappear on the bank of the Thanni stream. These beds are first seen along the West bank of the Moo stream, and are well displayed in a feeder of the Moo, near Kondeing-zu (or Kondein-keng) (19° 28′; 94° 41′), and thence on to Khyoungtha (19° 28′; 94° 40′). The beds near Kondeing-zu are in places vertical, or with a high dip to west-by-north; between this and Khyoungtha the high dip is maintained, but is reversed, varying from 70° east by north to 70° as an average east by south. Near Khyoungtha the dip is less, and small anticlinal folds are indicated by a few reverse dips; hereabouts also a little limestone is seen lying about in the stream in the form of large boulders, which, though I did not discover it *in situ* at the time, I now recognise as the limestone at the base of the upper Axial division. The rocks along the Moo stream are much distorted, but I imagine they form part of the sharp synclinal fold, whose axis passes somewhere about the village of Kondeing-zu, and which is cut off by the boundary fault close to the Moo stream.

At Khyoungtha these beds are left, when the ascent of the hill or ridge is commenced, which separates Khyoungtha from Pathi (19° 28′; 94° 35′). No good section is seen on the steep hill sides, but the beds passed over are thick-bedded grits, with rusty and glazed surfaces, especially the coarser and more conglomeratic beds. The prevailing dip of these beds is east-by-north; but this is occasionally seen reversed, as though from small local foldings. The beds are much indurated, and seamed with calcite, and seem to extend to near Pathi. The village of Pathi is situated on a feeder of the Mahton stream; and directly this small stream is crossed, and the eastern branch of the Arakan range gained, running up to the frontier peak of Kyeedoung, a different description of beds is at once met with—softish subschistose beds, wherein the calcite veins are replaced by veins of quartz very sparingly distributed. It is only in the stream that a view can be got of these beds, as they decompose readily at the surface into a clayey soil covered here with dense virgin forest, the unchallenged domain of the elephant, tiger, and other large game. Very similar beds to those are seen further south on the ascent to the Arakan range by the little-used path, from Leppandaing (19° 20′; 94° 41′) and Wetto (19° 20′; 94° 40′) to Mai-i; but I know of no good sections of either these subschistose beds or the overlying silicious grits. In none of the above beds have I noticed any fossils. I will here therefore give the best section of the upper division of the Axials I am acquainted with, commencing with a bed which I take as the base of the division from its containing a few fossils and thereby affording a recognisable horizon for classifying the group.

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[1] *Mem. Geol. Surv. Ind.*, Vol. X, pp. 319-325, (1873).

Hlowa stream section.

SECTION IN THE HLOWA STREAM (ASCENDING).

Lower Axials.

Dark and greenish flaggy shales . . . . . . Sandstone and shales . . . . Dark thin-bedded shales, with carbonaceous markings .	Seen over 300 feet.

Upper Axials.

	Ft.	Ins.	Ft.	Ins.
(*a*) Thick-bedded shale passing into dark massive arenaceous shales, with hard nodules interspersed. (*Cardita* and small indeterminable gasteropoda)	..		110	0
(*b*) Dark blue shale, with a few sandstone bands . .	17	0		
Rubbly limestone conglomerate, with a little blue shale, bedding indistinct	10	6		
Hard, coarse conglomerate, with a little fine sandstone	5	9	33	3
(*c*) Shales and sandstones in thick and thin beds . .	188	0		
Fine thin-bedded gray argillaceous sandstone, with shaly partings	34	0		
Ditto thicker-bedded . . .	4	6		
Thick-bedded sandstones in one and two feet beds, with shaly partings	64	0		
Coarse, hard, subporcellaneous grit	5	0		
Thin-bedded shales and sandstones and one six-inch bed	68	0		
Conglomerate	3	0		
Shaly beds	21	0		
Hard argillaceous subporcellaneous sandstones .	102	0		
Shaly beds	102	0		
Massive argillaceous subporcellaneous sandstone .	34	0		
Shaly beds	21	0		

	Ft.	Ins.	Ft.	Ins.
Hard subporcellaneous sandstone	3	0		
Shaly beds	5	0		
Massive thick-bedded gray white-speckled grits	25	0		
Ditto, ditto, but in thinner beds	129	0		
Shaly beds	25	0		
Thick-bedded subporcellaneous white-speckled grits	43	0		
Ditto, but in thinner beds	12	0		
Dark shales and sandstones	51	0		
Bluish gray subporcellaneous sandstone	21	0		
Dark sandstones and shales	129	0		
Dark shales	45	0		
Creamy blue subporcellaneous sandstone	5	0		
Sandstone and shales (ill seen)	215	0		
Massive white-speckled grit	11	0		
			1,364	6
(*d*) Shales and sandstones in from six to eighteen inch beds	475	0		
Massive greenish gray sandstone	4	0		
Shales with a few thin sandstone beds	172	0		
Shales with a few thick sandstone beds	475	0		
Sandstone with a few shaly partings	43	0		
Very massive blue and gray sandstone	52	0		
			1,221	0
(*e*) Dark harsh shales and dark thin-bedded sandstone, none over four inches	154	0		
Massive argillaceous sandstone	5	0		
Dark hard shales and sandstones as above	319	0		
Ditto, but thicker bedded	25	0		
Ditto, but thinner bedded as above	129	0		
Shales and sandstones	344	0		
			976	0
(*f*) Pale massive sandstone, gritty and in parts conglomeratic	103	0		
Pale gritty sandstone thin-bedded, gray and creamy	12	0		
Ditto, massive	6	0		
Hard gray sandstone	26	0		
			147	0

At this point the faulted boundary of the group would seem to come in, but it is not very clear, and may in reality be a few hundred feet higher.[1]

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[1] This fault was also remarked by my colleague Mr. Fedden in his notice of this section but his account does not enable me to correlate his observations with my own with any great closeness; but it is certain that, theoretical considerations apart, my colleague's views of a fault crossing the section here tallied with my own, though arrived at quite independently of one another. (Theobald.)

The above section may be thus epitomized :—

	Ft.	Ins.	Ft.	Ins.
Lower Axials.				
Shales and sandstones (seen)	300	0		
Upper Axials.				
(*a*) Cardita shales	110	0		
(*b*) *Halobia* limestone, shales, etc.	33	3		
(*c*) Freckled grits, etc.	1,364	6		
(*d*) Shales and sandstones	1,221	0		
(*e*) Shales and sandstones	976	0		
(*f*) Sandstones, etc.	147	0		
			3,851	9

The really characteristic portion of the group is that embraced in subdivisions (*a*), (*b*) and (*c*).

(*a*) These shales are exposed just below the mouth of the Thayet stream, a small feeder of the Hlowa, and are here characterised by a species of *Cardita* which is not rare in them, and not unfrequently presents both valves united. A few small gastropods are also present, but Dr. Stoliczka has been unable to specifically determine any of them ; neither have these fossils been noticed elsewhere.

(*b*) This bed I have termed the *Halobia* limestone, though at this particular point it does not contain that fossil ; but I have little doubt that it is one and the same bed. The limestone here seen is a mixed rock, partly shale and conglomerate and partly a rubbly limestone. It contains here a species of echinoderm, though not in a condition to be identified, and it is the presence of this fossil elsewhere which helps to identify this rather variable bed. In the small stream near the Thanni stream, almost where this group ceases out, a thickish bed of grey limestone occurs, which may be identified with bed, *b*, of the Hlowa section by the occurrence in it of numerous specimens of the same echinoderm, but not sufficiently well preserved for specific identification. This is the same limestone which I have described as found between Kon-ding-zu and Khyoungtha, near the frontier, and though it would seem to vary much in mineral character, it may generally be found where this upper division of the group is well exposed. North of Nattoung, and some one and a half miles south-west from Thabie-gaing, a small outcrop of what I take to be this limestone is seen on the crest of a low hill in which a few specimens were obtained of a shell which Dr. Stoliczka considers to be *Halobia Lommeli*, a characteristic fossil of the Triassic group in the Himalayas of Spiti. In the Pyagyee, a small feeder of the Maday river this limestone is seen, of various tints of pink and yellow, and occasionally converted into a white crystalline rock, which change is probably induced by the

Triassic outcrop.

near proximity of the large mass of serpentine of Shynbaiahn hill. An outcrop of this rock also occurs near the Mahton, about one mile North-west of Lepangain, where it appears to strike west-south-west, and three miles north-east of this outcrop is a large patch of limestone forming a low hill, the dip not being well seen, whilst two and a half miles south of the first outcrop is another large mass of limestone which forms the summit of a hill. The ascent to this last mass of limestone lies over typical upper Axial strata, and I believe all these three outcrops belong to one and the same bed. Although the limestone would here seem to be more developed than farther to the south, I noticed no fossils in it, which is, I think, due to the greater amount of alteration the rock has here undergone. At various other spots traces occur of this bed, but nowhere has it yielded fossils capable of determination (save at one spot), and that only the single species of *Halobia* above named.

Whilst, therefore this limestone is the only bed of the group which has yielded any reliable evidence of its age, meagre as that evidence is, the next division (*c*) of the group is the most important as regards the peculiar petrological character of its beds, which enable us to recognise them with confidence wherever met with. The characteristic beds of this division, which embraces over thirteen hundred feet of beds, are white freckled grits and conglomerates, not usually very coarse (though here and there coarse beds, almost pseudo-breccias, occur), and cream-coloured argillaceous sandstones, often having a sub-porcellaneous appearance, or sometimes something of a lithographic look. Small white quartz pebbles abound in the finer conglomerates, but the coarser conglomerates are mainly composed of argillaceous sub-schistose rocks, which suggest the idea of their being derived from beds of the lower division of the group, though this is probably fallacious. The coarsest beds I have anywhere noticed occur in the Shu (Shoo) stream above Sabatan (19° 10′; 94° 51′). In the lower part of the Shu, an enormous thickness of beds is fairly exposed, but greatly disturbed and faulted towards the boundary of the group. Higher up the stream the dip is more regular, always high, but varying from North-east-by east, round to East-north-east. Some of the sandstones are hard, and have strings of quartz pebbles irregularly disseminated through them, the pebbles sometimes, however, being accumulated in bands. In one spot I noticed among the finer ingredients a well rounded quartz boulder six inches in length in one of these conglomeratic sandstones; but such instances are rare. Some of the coarser beds up this stream are, however, of such a character as to overtax my power of adequately describing. One of the most remarkable, and which will explain the type of the rest, was just below a spot where a wall of rock crossed the stream, rendering it impassable for elephants. The bed in question was a sandstone of ordinary appearance enough, save that embedded in it were large angular fragments of a sub-schistose rock belonging to some older group. Many of these included fragments were nearly a foot in diameter, and, as far as I could judge, were truly derivative fragments, and not (as occasionally is seen) fragmentary portions of a rock contemporary with the beds which seem to enclose them. The bed was not in other respects very conglomeratic, nor were these fragments very numerous; and I suppose the appearance, however created, was due to causes extremely local. I nowhere else noticed any similar bed to this, and the general character of the coarser conglomerates of this group is that of a rock composed of partially or well rounded fragments, with a rather sparing amount of matrix, and in places only displaying a tendency to the angularity of a breccia."

Of the serpentines which occur in this area Theobald remarks[1] :—

Serpentine in Axial series.

" The first mass of serpentine south of the frontier is that which constitutes Bidoung hill, five miles South by east of Pathi. Descending the Mahton from the North, Bidoung hill has the appearance of being almost isolated from the main body of the Arakan range, so much so that it is not clear, at the distance of a few miles, on which side of the hill the Mahton will flow. On reaching, however, the Northern flank of Bidoung, the Mahton turns somewhat to the East, and flows through a gorge of serpentine rock, bare, sterile, and picturesque, with Bidoung on the right and a somewhat smaller peak of similar character on the left. The serpentine area which is here traversed by the Mahton extends some five miles in a North-by-east or North-north east direction, with a mean width of perhaps two miles ; and in addition to the main stretch of this rock, a small ridge runs down from it along the East bank of the Mahton to nearly opposite the village of Kaingi, though without appearing in the bed of the river. This is the largest single mass of serpentine in the province, and has produced greater alteration in some places among the rocks in contact with it, than I have elsewhere observed. This is especially the case on the flanks of Bidoung hill, where, as the boundary of the serpentine is approached, the rocks for a short distance from the junction become converted into gneissose and chloritic schists. Even here, however, this effect is local, and is much less visible on the East of the Mahton along the minor range opposite Kaingi than on the flanks of the larger mass of Bidoung. I think it probable, however, that this may partly be due to the composition of the beds in contact with the serpentine rather than to any more occult cause, since, *caeteris paribus*, the behaviour of beds so circumstanced, and the kind and degree of metamorphism produced in them, would mainly depend on their composition, and this probably explains why at one spot a perfect metamorphic schist is produced, whilst at others a less degree of change is observable. I did not notice any veins of serpentine in connection with the bulk of the rock of which Bidoung is composed, and the same remark applies to other localities where the rock is largely developed ; and veins, if such is there occurring subordinately among the stratified Axial strata, as on Shuaydoung and the Hlowa stream. In the Hlowa stream the serpentine forms a bed or dyke among Axial strata, the precise position of which in the group is not clear. It occurs considerably above the Thayet stream, where the section of the upper Axials commences, and is probably intercalated among beds lower in the series than those in the above section. It is no doubt connected with the occurrence of serpentine on Shuaydoung, which in this locality seems to be very sparingly developed compared with other places. South of the Hlowa a little serpentine in the form of rolled pebbles occurs in the Shu (Shoo) stream, and in the upper portion of the Ngawet stream above Kwon-doung. I did not detect the rock *in situ* in either stream, but it might have been derived in the Shu stream from small veins in the altered Axial strata rather high up, where considerable disturbance is seen. In the Ngawet stream I failed to find any likely source for the pebbles seen in the channel, and as in both these streams the pebbles did not increase in number or size as the channel of the stream was traced to its source, I am disposed to think that these pebbles may have been derived from the mass of serpentine, to the south, on the banks of the Maday

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[1] *Mem. Geol. Surv. Ind.*, Vol.X. p. 144, (1873).

> stream, full proofs existing of the free transport of boulders from farther sources than this, at a time anterior to the final excavation of the present river courses as I have already described of the boulder drift found at high levels along the course of the Maday and this part of Pegu generally.
>
> We now approach the second area of serpentine outbursts, presenting three distinct foci of activity, though all ranged in close proximity to the Axial boundary, and in part coinciding with it. The first and most remarkable display of this rock is seen just above the village of Letpangon (19° 3′; 94° 55′) on the Maday. A wall of serpentine here crosses the stream and appears to divide the Axial from the Nummulitic group. In the Axials, above the dyke (if such is its nature), the utmost confusion and alteration exists, especially a little way up the stream, where some limestone occurs, which is doubtless the Triassic limestone (*b*), but so altered as to present no trace of any organism whatever. Below the dyke and along the boundary, the utmost mechanical disturbance prevails among the newer strata, but nothing like the alteration seen among the Axials, and it seems clear that whilst the action of the serpentine on the Axials caused or coincided with a notable amount of metamorphism among them, the action of the serpentine on the Nummulitics was almost purely mechanical in character in its effects. This ' wall ', as I have termed it, has every appearance of being a dyke stretching on either side of the Maday, for about five miles in extreme length, but nowhere exceeding a quarter of a mile in breadth, and in some places south of Letpangon not attaining more than one hundred and fifty yards, if so much, where steeply scarped by a small feeder falling into the Maday stream just above it. It runs in a slightly curved line, and at either end terminates abruptly without any indication of further continuance."

Made *chaung* area.

Chromite occurs in small segregations in the Bidoung serpentine but none occurs in that of Thayet-chaung to the south. In the latter area north-west of Gyobin (19° 2′; 94° 57′) the hills are formed of tuffs and grits. The same series continues to the westwards where one mile east by north of Thayetchaung (19° 3′; 94° 55′) bedded ashes dipping W. 10° S. at 20° are well exposed. The thickness of the individual beds varies from two inches to six feet. At the south-west end of Thayetchaung village vertical tuffs strike N. W. by N. Similar rocks are then seen dipping 70° N. E. by E., a little further west and are followed by contorted shales with limy intercalations which continue to the serpentine intrusion half a mile west of Thayetchaung village. The serpentine band is from 500-600 feet thick, dips E. 30° N. and is underlain by tuffs; the river passes through it in a gorge. No trace of chromite could be found in either the main mass of the serpentine or as boulders in the stream bed. The eastern boundary of the serpentine exposure cuts across the ridge which runs south from a quarter of a mile south-west of Thayetchaung village. This ridge is made up of conglomeratic debris on which boulders, mostly of a quartzitic nature, running up to two feet in diameter occur at a height of from 150 to 200 feet above the river level. At the bend of Made *chaung*, one mile south by east of Thayetchaung the serpentine is overlain by tuff and ashes dipping N. N. E. at 30°. It is followed to the east by rather fine tuff and grits with occasional conglomerates dipping E. 20° N. at 30° to half a mile west by north of Mibauk Atet (19° 2′ ; 94° 56′) where fine tuffs and ashes dip south-west at 40°. Between Mibauk Atet and Gyobin, ashy sandstones dip 70° N. E. by N.

Dr. Cotter[1] states that it is quite impossible to suppose that the serpentine intrusions are as late as Eocene, as they nowhere affect Eocene rocks. Whilst one may agree that the serpentine intrusions are of pre-Eocene age, one can hardly accept the substantiating statement on which it is based, as owing to metamorphism and the consequent destruction of fossil evidence the age of the rocks surrounding the serpentine intrusions is unknown and it is quite impossible to say whether Eocene rocks are affected or not. Vulcanicity as evidenced by ashes and tuffs certainly continued into the Eocene, and we can only regard these latter as outward manifestations of plutonic and hypabyssal intrusion.

From the descriptions given of the Axial and boundary rocks no reader can but be struck with the very uncertain nature of the boundary of all observers. Added to this the tuffs and ashes west of Gyobin are very characteristic and from his descriptions, I should certainly correlate them with the upper Axials of Theobald's Hlowa *chaung* section. His freckled grits are almost certainly tuffs and his porcellanous rocks fine consolidated ashes. Theobald is, however, strangely silent about the rocks above the Thayetchaung serpentine. Possibly this is owing to the fact that in the stream no good section can be made out. One must however conclude that all along observers have been mapping a boundary separating altered from unaltered rocks—I certainly have—and that these rocks range in age from Eocene downwards.

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[1] *Mem. Geol. Surv. Ind.*, Vol. 72, pp. 35, 36, (1938).

CHAPTER VI.—DETAILED DESCRIPTION OF ROCKS:

Lower Eocene.

North of latitude 20° 30′ it is possible to divide the Eocene rocks into the following series:—

Sequence north of latitude 20° 30′.

Yaw Stage.
Pondaung Sandstones.
Tabyin Clays.
Tilin Sandstones.
Laungshe Shales.

At latitude 20° 30′, the Tilin sandstone dies out and although inconsistent sandstones and conglomerates do occur in the Lower Eocene to the south their correlation is not possible, and hence the lower three series given above have been classed together as Lower Eocene.

Lower Eocene rocks west of Sidoktaya.

On the Palaung *chaung* at Aukpon (20° 28′; 94° 15′) in the lower part of this series (L. Eocene) faulting occurs and the rocks, which consist of fine-grained sandstones, coarse grits, and conglomeratic grits, are all much disturbed and their relations indistinct. Westwards up the *chaung* exposures are rare; where they do occur they consist of sandstones all so jointed and broken that dips in them are not perceptible until the 910-1282 ridge is reached three miles west of Aukpon (20° 28′; 94° 15′) on the reserved forest boundary, where nummulitic sandstones dip E. 10° N. at 60°. Towards the west, in crushed and contorted shales reinforced by sandstone bands, the dips steepen to the conglomerate which has been taken as the lower boundary of the Eocene. A similar broken series of sandstones and shales is met with along the Sami *chaung* west of Sidoktaya (20° 27′; 94° 14′ 30″).

Lower Eocene rocks east of Sidoktaya.

East of Sidoktaya disturbed rocks occur until the Mon *chaung* is crossed and the shaly series underlying the massive Pondaung sandstones is reached. At Thayangaing (20° 29′; 94° 16′) this series consists of sandstones with hard blue limy bands and blue clays or shales. They are unfossiliferous, dip east by north at about 30° and pass upwards into blue shales to the base of the Pondaung sandstones, which is characterised by an *Ostrea* band.

Up to a height of 50′ above the Thayangaing (20° 29′; 94° 16′) stream level, pebbles of Axial debris with diameters up to 8″ occur in the soil cap.

To the south at the mouth of the *nala* which joins the Mon river half a mile north-east of Nyaung-aing (20° 27′; 94° 16′), sandstones grading to blue shales or clays, with harder limy bands, dip east at 70°. They occur on the west side of a small fault which strikes N. 40° W. about 250 yards from the confluence. Numerous small waterfalls occur in the bed of the stream where clays or shales underlie the harder limy bands. Eastwards the series is a shaly one, the soil cap is thick and exposures are rare even in the *nalas* until the Pondaung sandstones are reached. At the base of the latter series the *Ostrea* band noted further north is still found to occur.

Magyisu Area.

Blue shales occasionally broken and contorted fill in the angle formed by the scarps of Pondaung sandstone N.N.E. of Magyizu (20° 26′; 94° 18′). In the *nala* north-east of Pazaw (20° 27′; 94° 18′) they dip steeply and occasionally weather conchoidally whilst harder limy bands are characterised by cone-in-cone structure. The dips vary from east to west but are all very steep, as the stream bed follows the line of faulting which separates the syncline to the north-west from the main Nwamataung range. Fragments and blocks of fossiliferous limy rock apparently from the base of the Pondaung sandstones occur in both the main *nala* and the small subsidiary *nalas* which join it from the scarps to the east and west.

In the Pazaw *nala* (20° 27′; 94° 18′) about a mile north by west of Pazaw the passage beds from the Pondaung sandstones to the lower shale series form a cliff of limy strata and shales from 150-200 feet high. The *nala* cuts through these rocks in a series of waterfalls. On the east side of the Pazaw *nala* (20° 27′; 94° 18′) a fault runs north-east and continues south to half a mile west of Magyizu (20° 26′; 94° 18′) whilst another running approximately north-west joins it three quarters of a mile north of Pazaw.

Kyaukpyu Area.

To the south these Lower Eocene rocks are all much disturbed and this is especially the case where they consist of shaly strata or ashes, although even where sandstones and conglomerates occur the dips in them are all very discordant. At Kyaukpyu (20° 23′ 30″; 94° 15′) in the gorge in the Thitmyit *chaung*, north by east of the village, dips range from 30° E. 40° N. to 80° E. 30° N. at the north-end in sandstones and conglomerates, to 30° N. in conglomerates at the south-end of the gorge. These latter conglomerates contain soft casts of small nummulites.

To the south and west of the village of Thetle (20° 22′ 30″; 94° 16′), grits, dipping 50° E., are underlain by sandstones, shales and lavas whilst almost vertical and sometimes contorted sandstones and shales alternating with ashes are found in the intervening country between Thetle and Munzaw (20° 21′; 94° 17′). A very similar series occurs between Munzaw and Hpa-aing although one mile south by east of Munzaw village (20° 21′; 94° 17′) a limestone was discovered to contain the Laki foraminifera *Nummulites atacicus* and *Assilina granulosa*. Big boulders of Axial detritus are strewn about the surface in the lower ground formed by these Lower Eocene rocks west of the Mon *chaung*.

Hpa-aing.

It is obvious from the foregoing account that considerable faulting and folding has taken place along the Axial-Eocene boundary in this northern area. In addition to this the Lower Eocene outcrop at Hpa-aing has been reduced to about one and a half miles. This outcrop must include the Tabyins, Tilins and Laungshes of more northern latitudes, if they are present, and one fails to see what has become of them. The Upper Eocene (Pondaungs and Yaws) and Pegus to the east present a normal monoclinal sequence and no unconformity can be made out below them. The presence of the Laki forms, *Nummulites atacicus* and *Assilina granulosa,* points to the presence of the Laungshe shales. The Tabyins and Tilins must therefore be overlapped by the Pondaungs at this point or cut out by faulting.

Possible overlap of Upper or Lower Eocene.

In his Progress Report for 1912-13 Cotter describes the rocks of the Hpa-aing--Ngape valley to the south as a series of unfossiliferous rocks which are identical with the Lower Eocene of Theobald. There is, according to Cotter, very little doubt as to their age since they overlie the probably late Cretaceous serpentine and underlie strata with Khirthar fossils. But it is uncertain to what part of the pre-Lutetian Eocene they are to be preferred.

Hpa-aing—Ngape valley.

They consist of (1) coarse micaceous sandstones of a pepper-and-salt appearance, (2) indurated white fine-grained porcellanous sandstones, (3) conglomerates with pebbles of varied size from that of coarse shot to that of a tennis ball or larger.

Nearly all the small hill-ranges at the foot of the Yomah are made of conglomerate, which may be found at any horizon of the

Lower Eocene, and is especially developed at its base. (4) Shales are also found (although they are not very common) in the Lower Eocene. An excellent exposure of blue shale is seen in the Zi *chaung* opposite Letpantaga village (20° 18′; 94° 21′). The shale is unaltered. A careful search was made for fossils in this and other localities by Cotter, but was unsuccessful.

Dip of Lower Eocene Rocks.

The dip of the Lower Eocene rocks is fairly constant and is usually in a direction between 40° and 60° east of north. The angle of dip varies from 30° to 50°, but in two places local dips of over 70° were obtained.

Basal Eocene: Paunggyi.

South-east of Paunggyi (20° 2′; 94° 32′) flaggy sandstones, grits, conglomerates, and intervening shales are present. The pebbles in the conglomerates are generally of quartz but soft mudstone pebbles too, are seen. Occasional whitish highly siliceous fine-grained bands occur in the conglomeratic series. A few *Cardita* casts and broken specimens of *Turritella* were found at the falls between Hills 1126 and 1105 west of Paunggyi.

Axial-Eocene boundary south of Latitude 20°.

To the south the Axial boundary has only been interpolated from observations made on isolated traverses by Hayden, Datta, Bion and Sethu Rama Rau. Hayden's observations on these Lower Eocene rocks near Shauktaung (Sheet 84 L/8) were given in discussing the Axial rocks on pages 182 and 183 (*ante*).

Thakutkyin area.

According to Mr. Sethu Rama Rau the foot and spurs of the Chin Hills situated to the south near the village of Thakutkyin (19° 42′; 94° 37′) give a good section of Lower Eocene rocks; they consist chiefly of argillaceous limestones and shales with a few bands of sandstones of a brownish tint. One of the limestones is made up of boulders of nummulitic limestones cemented together with a calcareous cement. The nummulites were examined by Cotter who identified the Laki form *Nummulites atacicus*[1] in them. Cotter in the paper quoted gives a list of localities from which Mr. Datta collected fossils whilst making a traverse across the Arakan Yoma further south. They are as follows:—

(1) Not quite half a mile west of Kyuni village (19° 33′; 94° 41′ 30″) Sheet 114.

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[1] *Rec. Geol. Surv. Ind.*, Vol. XLI, Pt. 4, (1912).

(2) South-east from Kyuni to Kondeingon (a deserted village not marked on the map).

(3) Half a mile north by west of Pebingon—(19° 28′; 94° 41′) Sheet 115.

These are the localities from which *Nummulites atacicus* and *Assilina granulosa* were obtained, the occurrence of which was quoted by Tipper in his memoir on the Andaman Islands.[1]

Again according to Cotter (*ibid*)—

> 'Mr. Datta found a limestone rock to the west of this nummulitic bed, half way between the villages of Kadein (19° 22′; 94° 39′) and Pyugan (19° 23½′; 94° 41′) which he states is again visible 1¼ miles west of Ywathit (19° 15′; 94° 44′). He points out that this last locality is the one referred to by Theobald.'[2]

The following is Theobald's[3] section of Lower Nummulitic strata above the village of Ywathit, (19° 15′ 45″; 94° 43′ 30″) in ascending order.

Ywathit. Theobald's Nummulitic sequence.

TRIASSIC STRATA.

Nummulitics.	Ft.	In.
Hard sandstones (ill seen)	44	0
Shales (ill seen)	600	0
Blue friable shale, with numerous bands of sandstone	145	0
Ditto with shales predominant	81	0
Hard blue sandstone	3	0
Shale and sandstones, former predominant	12	0
Hard blue sandstone	2	6
Shales and sandstones, latter thin, former predominant	250	0
Blue friable shale with harsh blue and grey sandstone	51	0
Blue shale with sandstone courses	17	0
Blue and grey harsh sandstone and shales, former predominant	173	0
Blue and yellow shales, with hard sandstone courses, in regular beds, one to four inches	16	0
Pale bluish grey sandstone	1	0
Blue and yellow shales as above	78	0
Yellow shales, with hard blue sandstone courses	25	0
Shaly beds (ill seen)	103	0
Blue shale	1	0
Hard grey argillaceous sandstone, rather shaly	1	6
Sandstone in one and two-inch beds	51	0
Grey shale and shaly sandstone	5	0
Blue and yellow shale	65	0
Shale and sandstone (ill seen)	85	0
Total	1,810	0

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[1] *Mem. Geol. Surv. Ind.*, Vol. XXXV, Pt. 4, p. 200, (1911).

[2] *Rec. Geol. Surv. Ind.*, Vol. IV, Pt. 2, pp. 102, 134, (1871).

[3] *Mem. Geol. Surv. Ind.*, Vol. X, pp. 290-291, (1873).

TRIASSIC STRATA—*contd.*

Nummulitics.	Ft.	In.
(Here comes in the village of Ywathit, below which the section is merely estimated, not measured)—		
Hard sandstone	7	0
Greenish grey flaggy sandstone and bluish grey arenaceous shales, with carbonaceous markings	45	0
Dark shales with a few nodular courses of indurated marl, with a few sandy bands here and there	275	0
Fine pale greenish sandstone, massive above, less so below .	45	0
Fine pale greenish sandstone, massive above, more flaggy . .	50	0
Blackish grey arenaceous shales	255	0
Pale greenish grey arenaceous shales, and greenish and yellowish grey sandstone in intercalated thick beds, fine grained, compact, and with carbonaceous marks and rippling . . .	180	0
Massive argillaceous greenish sandstone, with an amylaseous fracture	100	0
Massive argillaceous greenish sandstone, with shales, thin bedded	200	0
Dark shales, with a few sandy beds	200	0
Dark shales, but the sandstone more thickly bedded, and less regularly dispersed, ripple marks in places	190	0
Grey massive sandstone, thick bedded	260	0
Massive sandstones, thick bedded with occasional beds of shale .	500	0
GRAND TOTAL .	4,117	0

Of this section Theobald states :—

> 'Beyond carbonaceous markings, I noticed no fossil whatever; many of the beds however are badly seen, and the chief value of the section consists in showing the astonishing thickness of this early Tertiary group. It must, however, be remarked that in the total absence, from this lower portion of what I have designated the Nummulitic group, of all fossil evidence as to its age, it is possible that some of the beds may be of a greater age, though this cannot with certainty be either affirmed or denied.
>
> At the point where the above section is taken, the Nummulitic group is wider than almost anywhere else, its width being thirteen miles; opposite Myanaung the width is only ten miles, and at Henzada not more than two.'

Width of Eocene outcrop.

Theobald is mistaken in the width of the outcrop at this point, as the Eocene strata are transposed five miles by folding and strike faulting on a N. N. W. axis, and a cross fault running east by north on the north side of Shwenattaung pagoda.

Fauna : Ywathit.

The fossils from Theobald's Ywathit locality were examined by Mr. Tipper[1] who found them to consist chiefly of fairly well-preserved *Carditæ* and some poor gastropods (*Turritella*, etc.), the *Carditæ* being all of one species and 'easily recognised as identical with the well-known *Cardita* (*Venericardia*) *Beaumonti* d' Arch. of Sind and Baluchistan', a species of Upper Cretaceous age.

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[1] *Rec. Geol. Surv. Ind.*, Vol. XXXV, p. 119, (1907).

Theobald's Halobia Limestones.

The limestones which overlie these '*Cardita* shales' are called by Theobald '*Halobia* limestones' although at that particular point they do not contain *Halobia*. The locality from which Theobald's *Halobia* specimens purport to come is one and a half miles south-west of Thabyegaing (19° 2'; 94° 57') some 20 miles further south. The correlation of these two limestones appears to me therefore to be weak, irrespective of the fact that there is a grave doubt whether the specimens identified as *Halobia* by Stolicska come from the locality cited at all.

As I have already stated (pp. 194-195) the serpentines of Made *chaung* are overlain by what are ostensibly Eocene rocks composed of tuffs, conglomerates, ashes and grits and these if continuous along the strike for but four miles to the south-east must overlie the sole locality in which Theobald purported to find Triassic fossiliferous strata. In the area under description therefore Cretaceous strata have been proved in the arc formed by the main range of the Arakan Yoma between the Hpa-aing serpentines and the Thayetchaung ones. Just north of Hpa-aing Lower Eocene rocks were proved by the occurrence of *Nummulites atacicus* and *Assilina granulosa* whilst on Made *chaung* the first fossiliferous occurrences above Theobald's purported Triassic one, are north-east of Gyobin, (19° 2'; 94° 54') where foraminifera typical of the Upper Eocene occur.

CHAPTER VII.—DETAILED DESCRIPTION OF ROCKS: UPPER EOCENE STRATA OF MAIN RANGE.

In the northern part of the area I have been able to divide the rocks of the Upper Eocene into the divisions recognised further north, namely, the Pondaung sandstone below and the Yaw shales above.

Pondaung Sandstone.

The name Pondaung sandstone was first adopted by Dr. Cotter to designate the formation, mainly sandstone, lying between the Yaw shales above and the Tabyin clay below. According to Cotter, previous observers of the Yaw river section to the north, had correlated the rocks exposed with the basal beds of the Pegu system in North Minbu, owing to their lithological resemblance. Cotter, however, was able to prove that the Yaw shales overlying them were Upper Eocene and that in consequence the Pondaung sandstone must also fall into the Eocene. This view was confirmed by Pilgrim from the mammalian fauna, and later by Bion by mapping along the strike into the North Minbu district, when the Yaw shales were found to be continuous with the shaly series containing the *Velates* beds of North Minbu.

To the north the Pondaungs form the Yeyotaung, Dudawtaung and Nwamadaung range; they are generally coarse, often current-bedded, sandstones with fossil wood and occasional bands of shale. The bands of shale become increasingly common towards the base and form a passage into the Tabyin clay series. Where the Pondaung sandstones enter Sheet 84 L/7 they have lost some of their prominence and become subordinate as a topographical feature to the Shwezettaw sandstones which overlie the Yaw shales and form the basal series of the Pegu system (*sensu lato*). Whereas to the north the Pondaung sandstones attain a thickness of 8,000 feet, at the north end of Sheet 84 L/7 they are only from 1,500-2,000 feet thick and become thinner to the south.

In the main range at the north-end of Sheet 84 L/7 they consist of alternating hard and soft fawn coloured sandstones more shaly towards the base and with occasional limy bands towards the top; they have a constant dip to the east of about 40°. In their upper horizons a little silicified fossil wood occurs and towards the base isolated traces of fossils are followed immediately above the Tabyin clays, by a fossil band characterised by *Ostreæ*. This occurs at the top of the alternating sandstone and shale series which form the passage beds into the Tabyin clays of the Lower Eocene below. To the west of the main range in this area the Pondaung sandstones occur in the Pazawbya syncline, the southern end of which terminates in the broken forest country round Pazawbya (20° 28½′; 94° 18′). At the south-end of this syncline the passage beds at the base of the Pondaung sandstones are well seen in a cliff section about 200 feet high; they consist of sandy limestones, limy sandstones and shales and are underlain by blue clays of the Lower Eocene which dip north-east, at low angles of from 15° to 20°.

In its duplication east of Thayangaing (20° 29′; 96° 16′) the Pondaung sandstones maintain the same characteristics as exhibited in the main range; they are marine at the base and a band of large *Ostræa* occurs, the same band being found again about two and a half miles to the south in the *nala* which debouches into the Mon *chaung* north-east of Nyaungaing (20° 26′; 94° 16′). A little fossil-wood occurs in the more estuarine series seen towards the upper limit of the sequence.

As will be seen from the map, faulting occurs in the Upper Eocene in this area, and besides the main strike faulting which duplicates the Upper Eocene of the main range in the Pazawbya basin to the west, minor faulting is also seen.

Yaw Stage.

The name Yaw Stage was given by Cotter[1] 'to the shale group which overlies the Pondaung sandstones in South Pakokku and which was first studied in the Yaw river section. Cotter estimated the thickness of the richly fossiliferous Yaw shales in the Yaw river section at from 1,600 to 2,000 feet and described them as a belt of soft blue shales, without much interbedded sandstones, which occupy long valleys or areas of low relief between the sandstones above and below. Cotter further stated that the lower boundary is sharp but that upwards the shales pass into alternating strata of shale and sandstone, and these into the more massive sandstones of the basal Pegu series. There was no evidence of unconformity between the Yaw shales and the basal Pegu rocks.

A full account of the fauna of the Yaw Stage so far as it is known is given by Cotter in the same paper.

In the vicinity of latitude 20° 30′, the rocks of the Yaw Stage in the main range are very much obscured by soil cap, but, from the isolated exposures seen, they appear very like the typical development to the north, and consist of blue shales with occasional sandy bands and red and yellow laminated limy sandstones. Debris from them consist in the main of concretionary calcareous nodules. Thin lenticular coal seams also occur and can be seen in the main *nala* north-west of Mile 26 on the Salin-Sidoktaya road. These coal seams have been reported on by Hallowes[1].

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[1] *Mem. Geol. Surv. Ind.* Vol. 72, p. 60, (1938).

Pazawbya : Yaw Stage.

Westwards around Pazawbya (20° 28½′; 94° 18′), the Yaw shales are well seen in their duplication in the syncline which is faulted against the main range. The series which in the main range must be about 800 feet thick are there much thinner (300′-400′); they pass downwards through an alternating series of soft and shaly sandstones into the Pondaung and through a similar series upwards into the Shwezetaw sandstones.

In the *nala* immediately south of Pazawbya (20° 28′; 94° 18′), bands of limestone with interbanded shales dip north at 15°. On the east side of the *nala* the dips suddenly change to 70° W. by N., whilst vertical and overfolded strata occur. The limestone bands are very fossiliferous and the following collection was made from the 8-foot band of limy fossil conglomerate which cuts across the *nala* 200 yards south of Pazawbya village.

Velates orientalis.
Velates schmiedeliana.
Cardium Thetkegyinensis.
Cardium sub-fragile.
Meretrix (Callista) Yawensis.
Corbula sub-exarata.
Drillia protointerrupta.
Volutoconus sp.
Natica sp.

The Yaw shales swing to the north-west from Pazawbya and at latitude 20° 30′, at the extreme north of Sheet 84 L/7, disappear, but their relative position is marked by a conglomeratic fossil band one and a half miles north-east of Thayangaing (20° 29′; 94° 16′) and about 400 feet below the summit of the Shwezetaw sandstone scarp. The fossil band is underlain by 50 feet of soft and then by alternating hard and soft sandstones, and the following collection was made from it.

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[1] *Rec. Geol. Surv. Ind.*, LI, pp. 34-49, (1921).

Velates schmiedeliana.
Cardium Thetkegyinensis.
Volutoconus birmanica.
Cardium sub-fragile.
Corbula sub-exarata.
Ampullina sp.
Solen sp.
Tapes sp.
Tellina sp.
Lucina sp.
Melongena sp.
Cytherea sp.
Ceritheum sp.
Capulus sp.
Cypræa sp.

Two and a half miles to the north, the Yaw Stage shales are again seen, and the stage is represented, about six miles further north around Kanbauk (20° 40′; 94° 18′), by an alternating, but on the whole shaly sequence, about 2,500 feet thick, coal seams occurring in the uppermost strata. This northerly alternating sequence is made up of three main bands of shale separated by two bands of sandstones, in which false-bedding and thin coal lenticles are common.

South of Latitude 20° 25′ :— Yaw and Pondaung Stages mapped as Upper Eocene.

South of latitude 20° 25′, no attempt has been made to map the Yaw Stage as a separate unit, and it has been combined with the Pondaung stage as the Upper Eocene. The whole of the scarp slope of the overlying Shwezetaw stage is steep, thickly forested and despite the steepness of the slope the soil cap is thick.

Mon *chaung* sequence.

To the south at Kyion (20° 22′; 94° 20′), where the Mon *chaung* breaks through the Nwamadaung range, the Upper Eocene consists of hard dark fawn coloured sandstones, bluish when unweathered, the harder ones being ripple marked, and occasional thin bands of sandy limestones. Near the top of the series one mile south-west of Kyion, the characteristic band of the Yaw stage containing *Velates schmiedeliana* occurs.

Unfortunately the other specimens extracted from the limy sandstone containing them—*Volutoconus sp.*, *Turritella sp.* and *Natica sp.*—were not specifically identifiable. Coal occurs towards the top of the sequence both north and south of the Mon *chaung* but only as lenticles. The thickest exposure seen—about three feet of coal or five feet including the impure shaly upper and lower portions—dips 36° E. by N., one and a quarter miles north-east of Kyion. The whole of the Upper Eocene sequence, hereabouts, cannot be more than 1,000 feet in thickness and is much less prominent, relative to the Shwezetaw sandstones, than at the north end of the sheet.

Upper Eocene east of Hpa-aing.

One and a half miles east of Hpa-aing (20° 15′; 94° 20′), another coal outcrop was seen in the same relative position in the Upper Eocene sequence. Hereabouts, the sequence is very badly exposed owing to the thick soil cap, although a little east of the reserved forest boundary and east of the junction of the paths from Hpa-aing and Kyaunggon, a hard massive limestone band, crowded with *Operculinæ*, is taken as marking the upper boundary of the Eocene. This horizon continues to the south-east and was noted by Cotter south-west of Kyauk-O (20° 10′; 94° 31′).

Man Chaung sequence.

In Sheet 84 L/12 to the south the Upper Eocene rocks were examined, first by Dalton[1] and later by Cotter[2]. The latter described the fauna from collections made by himself and Sethu Rama Rau along the section exposed where the Man river, in a series of meanders, cuts through the Lower Pegu and Upper Eocene sequence of alternating massive sandstones and shales. The top of the Eocene is characterised by the *Velates* horizon or G. band of Cotter and the base by a strike fault which runs N. W.-S. E. through the village of Sabagyidan and duplicates a part of the sequence. From Sabagyidan to the top of the Eocene the outcrop is one and a half miles thick and not less than 5,000 feet of strata are exposed in the main outcrop. The overlying Shwezetaw sandstone group consists of sandstones with intercalated grits, flagstones, and sandy limestones; they are fossiliferous and are characterised by the zone fossil *Ampullina birmanica*[3]. North-east of Peinhnebin (20° 5′; 94° 34′)

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[1] *Quart. Journ. Geol. Soc.*, LXIV, p. 604, (1908).

[2] *Rec. Geol. Surv. Ind.*, XLI, p. 221, (1912).

[3] Vredenburg: *Rec. Geol. Surv. Ind.*, LIII, pp. 359-369, (1921).

Coal : Mon Chaung.

a nummulitic limestone band has been taken as the upper horizon of the Eocene and occurs in shaly strata. Below this occurs an alternating sequence in which sandstones predominate over shales. The lithological assemblage is very similar, although alternations are more rapid and shaly, to that seen further north; the limy sandstones are fossiliferous but good specimens are most difficult to extract. In the slightly contorted shaly band dipping 70° N. E. down which the *nala* south-east of Peinhnebin flows, a seam of impure coal, mixed with carbonaceous shale, three feet thick was noted about one mile south-east of the village, whilst where the same stream debouches into the Man *chaung* three other small coal seams occur. Fifty yards to the east of the coal seams on the right bank of the Man river, oil seeps through the strata. These coal occurrences together with others which occur at about the same horizon in these upper Eocene strata south-west of Kyaukset, (20° 1′; 94° 37′) six miles to the south-east, have been reported on by Hallowes[1], who mentions their poor quality, lenticularity, and the general uneconomic nature of their occurrence.

Fauna of Uppermost Eocene : Man chaung area.

The upper limestone which has been taken as the top of the Eocene is a fairly constant horizon, and from the fossil conglomerate which occurs below it, Dr. Cotter[2] collected the following specimens from the localities noted to the south-east :—

(A) One third of a mile N. by E. of Kyaukset
Velates schmiedeliana Chem.
Cardium ambiguum Sow.
Conus literatus Linn.
Conus sp. cf. *substriatellus.* H. Woodward.
Corbula sub-exarata d'Arch.
Venus subovalis d'Arch
Cypræa elegans. Defr.
Volutospina sykesi d'Arch.
Voluta jugosa Sow.
Pleurotoma sp.
Vulsella sp.
Siliquaria sp.

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[1] *Rec. Geol. Surv. Ind.*, LI, pp. 34-49, (1921).
[2] *Rec. Geol. Surv. Ind.*, XLI, p. 226, (1912).

(B) Mile 28·2 on the Minbu-Ngape Road.

Cardium Ambiguum.
Rimella cf. *prestwichi* d'Arch & Haime.
Turritella sp. cf. *herberti* d'A. & H.
Corbula sub-exarata d'Arch.
Cassis sp.
Conus sp.
Triton sp.
Tellina sp.

From the *nala* half a mile south-east by east of Kyaukset, I collected the following:—

Cardium thetkegyinensis.
Cardium subfragile.
Tellina (*Arcopagia*) *tazuvensis.*
Corbula sub-exarata.
Velates schmiedeliana.
Volutoconus sp.
Nummulites yawensis.
Pleurotomaria sp.

Of the area to the west of the main range near Sabagyidan (20° 4′; 94° 34′) Cotter[1] says:—

> "At Sabagyidan village vertical and contorted beds are seen in the river section, and it is probable that a fault should be marked here. Whether there is a reduplication of the rocks exposed east of Sabagyidan or not, I am unable to say, but if this is not the case, the immense thickness of the Eocene is a difficult matter to explain."

Duplication of rocks by strike faulting.

This surmise of Cotter's I have shown to be correct, as immediately west of the site of Sabagyidan village (the village no longer exists), a small, shallow syncline, two and a half miles long, occurs on a N. W.-S. E. axis and is separated by strike faulting from the normal sequence to the east. On the south side of the Man river, the trough of the syncline is occupied by thick, massive limestones in which foraminifera occur; on the north side, the limestones have either been denuded away or have never been present, but a conglomerate which underlies the limestones on the south side is seen also on the north bank of the *chaung*. It is fossiliferous and contains nummulites. This conglomerate dips due east at 30° under the pagoda immediately east of Thakutpin (20° 4′; 94° 33′) village, swings round to the east, to the north-east of the village, and then to the south-east, half a mile east by north of the same place. The dip increases along the strike until at the latter point it is at 80° south-west. A similar band is found almost vertical and striking N. W.-S. E., one furlong west of Hill 676, half a mile south by west of Myeni (20° 5′; 94° 33′).

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[1] *Rec. Geol. Surv. Ind.*, Vol. XLI, p. 227, (1912).

The conglomerate passes downwards into 50 to 100 feet of sandstones and these are underlain by clays, characterised by calcareous lenticles showing cone-in-cone structure. Upwards, 200 to 300 feet of sandstones are found; but these sandstones are not very well seen owing to the thick soil cap on the north side of the Man and the talus slope of limestone detritus on the south side. Two miles north-east of Ngape a fossil band contains *Arca pondaunggensis* (Cotter) and *Nummulites yawensis* (Cotter).

Oligocene strata in duplication west of main sequence.

The conglomerate is of Pondaung sandstone age (Cotter's 'I' band), and in the Sabagyidan limestone the foraminifera include *Lepidocyclina elephantina*, *Lepidocyclina* sp., *Heterostegina* sp. and an unidentifiable echinoderm. This is the association found in the limestone of the Padaung clays to the east, and must be assigned to that horizon. The Upper Eocene and basal Pegu sequence therefore as seen in the Sabagyidan syncline is not more than 500 feet from the base of the Pondaung to the limestone horizon of the Padaung clays, whilst to the east, the same sequence is represented by not less than 5,000 feet of alternating strata.

No unconformity can be made out on the ground in the western duplicated sequence but overlap obviously does occur at this point although to the east the sequence appears quite conformable.

To the south-east the Upper Eocene rocks were first examined by Dalton[1] who notes—

Kyet-u-bok Band.

'Some 4½ miles north-west of Magyisan (19° 57′; 94° 42′) near the village of Kyet-u-bok (19° 49′; 94° 40′) in the chaung of that name, a bed of very shelly impure nummulitic limestone was found dipping 60° N. 60° E, the rocks above this limestone for some distance having the same strike and dip, but containing no nummulites. There is no doubt that this limestone, hereabout 25 feet thick is identical with that described by Theobald as marking the top of the Eocene in Lower Burma. The fossils determined from this bed were:—

Nummulites Beaumonti (?) d' A. & H.
Glycimeris sp.
Thracia sp.
Cardium ambiguum J. de C. Sow.

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[1] *Q. J. G. S.*, LXIV, p. 612, (1908).

Ficula Theobaldi Noet.
Oliva sp.

Descending in the series westwards, I met with two fossiliferous horizons; one being a thin white limestone made up of small globular bodies of Hydrozoan affinities and of various foraminifera, including *Operculina canalifera*, d'Arch., half a mile north-west of Kyet-u-bok; and the other, at a lower point in the series in the Kyet-u-bok *chaung*, yielded a worn specimen of *Ampullina ponderosa*, Desh. After striking the Minbu-Ngape road, north-west of the last named localities, blocks of arenaceous limestone were found full of *Ampullina grossa*, Desh, var. *oblonga*.'

Cotter[1] collected from the Kyet-u-bok band and obtained the following fauna :—

Orthophragmina omphalus Fritsch.
Nummulites beaumonti d'Arch.
Gypsina sp.
Campanile sp. cf. *giganteum*, Lamark.
Meretrix sp. cf. *parisiensis* Desh.
Conus brevis Sow.
Ampullina sp. cf. *sindiensis* Coss & Piss.
Cardium ambiguum Sow.
Ficula sp.

Stamp[2] describes this exposure of limestone at Kyet-u-bok in the following words :—

"This bed which the writer regards as the base of the Pegu System, is a well-marked calcareous band conglomeratic in places with small quartz pebbles. It is characterised by four species of foraminifera, always present, but in very variable proportions. They are *Nummulites yawensis* Cotter (formerly described as *Nummulites* cf. *beaumonti* and *N. beaumonti*) *Orthophragmina omphalus* Fritsch, *Operculina* cf. *canalifera* d'Arch., and *Gypsina globulus* Reuss. The associated mollusca include species common to the underlying Yaw Stage, notably *Velates Orientalis*. Whilst the species of foraminifera mentioned occur in enormous numbers in the bed itself they do not appear to range higher. It will be noticed that at least two of the foraminifera are Eocene forms. Taking a narrow palæontological view, one would be tempted to regard the Kyet-u-bok bed as Eocene. It is, however, distinctly a basal bed stratigraphically and its characteristics agree very closely with other typical basal beds. As a general rule one may say that the fauna of a basal bed of a formation comprises—

(*a*) Survivors from the preceding stage which occur in enormous numbers before their final extinction. Their number is frequently increased by the presence of numerous rolled specimens.

(*b*) Fore-runners of the succeeding faunas. It is the presence of these new elements in the fauna which should really decide its age"

Stamp's view of the basal Pegu age of the Kyet-u-bok bed has not been accepted by Burma geologists. The upper band occurs in the stream bed east of the position shown for the deserted village of Kyet-u-bok on the old 1″=1 mile map, Sheet 113. It consists of from 20—30 feet of foraminiferal limestone dipping 40° E. 25° N.; the foraminifera are all close packed and there is not the slightest evidence of transportation of any of the specimens. From my own experience I know that one of the species,—of which perfect specimens occur profusely in the band, *viz.*, *Orthophragmina omphalus*, Fritsch—breaks up practically *in situ* and all that remains after a very short transportation are the raised central portions, and flakes of the outer rim. Above this limestone are unfossiliferous shales whilst shaly strata underlie it, giving place south-west of the Kyet-u-bok location to fossiliferous sandy strata.

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[1] *Rec. Geol. Surv. Ind.*, XLI, p. 226, (1912).
[2] *Geol. Mag.*, LIX, p. 494, (1922).

The Upper Eocene sequence can be generalised, hereabouts, in descending order as follows :—

Generalised Upper Eocene sequence : Kyet-u-bok.

Shales (containing foraminiferal limestone bands).
Sandstones (fossiliferous).
Shales (containing sandy bands and coal seams).
Massive sandstones.

In the massive sandstones at the base of the series occur *Ampullina grossa* Desh. and *Alectryonia Newtoni* (Dalton).

Just over a mile west by south of Kyet-u-bok the massive sandstones containing *Ampullina grossa* and *Alectryonia newtoni* are underlain by foraminiferal limestone and the latter by more shelly limestone. A good section is seen on the watershed on the road from Kyet-u-bok to Yinshe where the series dips 45° E. 30° N. It consists of about 150 feet of shelly sandstone at the top underlain by 50 feet of foraminiferal limestone and the latter by 200 feet of shelly limestone. Sometimes included in this fossiliferous band which occurs intermittently along the scarp to the S. S. E. are specimens of *Velates* sp., *Conus* sp., *Turritella* sp. together with foraminifera. One and a half miles S. S. W. of Kyet-u-bok the following were collected :—

Ampullina sp. cf. *grossa* Desh ; *Ostrea papyraceus*, *Alectryonia Newtoni*, whilst from one and a quarter miles south-west of Tabingyo (19° 55′ ; 94° 42′) came the following :—

Velates sp.
Lithoconus sp.

Pecten sp.
Turritella sp.
Nummulites cf. *lœvigata.*
Nummulites cf. *obesa.*
Nummulites Cotteri.
Natica sp.
Ostrea fragments.

Magyisan.

West of Magyisan, I failed to pick up the Kyet-u-bok limestone band *in situ* although a band containing fragmentary fossils did occur at about the same horizon and pieces of foraminiferal limestone were found in the stream bed. To the south, however, at Tabingyo, immediately east of the village location (this village also no longer exists), a foraminiferal band containing *Discocyclinœ* and other fragmentary fossils dips E. 20° N. at 47°. Underlying it are blue shales with interbanded limestone conglomerates. The nodules in the conglomerates are concretionary and ferruginous. They lie in a matrix of blue shale in which minute fossil fragments occur. I failed to find a locality where good fossil specimens could be extracted from this band.

Uppermost Eocene: Tabingyo.

Duplication of Upper Eocene by strike faulting.

West of the main range in this vicinity, there is a duplication of these upper Eocene strata in the Yinshe-Manaung basin which lies four miles S. S. E. of that of Sabagyidan. It is characterised by a duplication of the Kyet-u-bok—Tabingyo limestone band, which is found to the west; and the fauna of the band, a mixture of the species found in the 'G' band of Cotter and the Kyet-u-bok band, confirms Dr. Cotter's correlation of the 'G' band with that of Kyet-u-bok. The following composite fauna was obtained from it:—

Cardium thetkegyinensis, Cotter.
Cardium sub-fragile, Bottger.
Orthophragmina omphalus, Fritsch.
Nummulites obesa.
Nummulites yawensis.
Operculina cf. *canalifera,* d'Arch.
Tellina (Arcopagia) tazuvensis, Cotter.
Athleta (Volutospina) annandalei, Vred.
Discocyclina papyracea, Boub, var. *javana* Verb.
Gosavia humberti d'Arch & Haime.

Corbula sp.
Chlamys sp.
Triton sp.
Chama sp.
Natica sp.
Orthophragmina sp. cf. *umbilicata*, Deprat.
Volutoconus birmanica.
Conus sp.
Turritella sp.
Orthophragmina sp.
Ficula sp.

This basin is also separated from the main sequence to the east by strike faulting, in this area demarcated by a fault valley.

Yinshe-Manaung basin.

The fossiliferous limestone band is overlain by bluish to fawn, fine-grained sandstones, which lie almost horizontal in the centre of the basin. It is underlain by sandstones, generally fine-grained and of a fawn colour, reinforced by harder gritty and shelly bands, which dip into the basin from the west and south at from 25° to 30°.

Foraminiferal limestones north of the main basin.

To the north of the main basin, outliers of the limestone band lie horizontal, capping the high ground one and one and a half miles respectively to the north-east of Padan (19° 58′ ; 94° 36′). These limestone bands are very ferruginous in places and very similar to the same bands west of Manaung (19° 54′ ; 94° 39′). Although they lie generally horizontal, dips do occur in them and evidently there has been a certain amount of local faulting. South-east of Hill 705 a western dip of 30° was registered, but to the east of this, easterly dips prevail. To the south along the eastern flank of the basin the soil cap is all very thick although fragments of foraminiferal limestone occur in it.

South-east of Manaung the foraminiferal limestones disappear in the thick soil cap and appear to be underlain just over a mile south-east by east of the village by contorted shales; in these blue shales further east, calcite showing cone-in-cone structure occurs.

West of Manaung the foraminiferal horizon is from 20-30 feet thick and consists of three bands separated by fossiliferous sandstone and shale.

To the west on the eastern slopes of the Pyaunggaung valley black cotton soil obscures the geology. On the west side of the

Pyaunggaung, sandstones and conglomerates dip east at varying angles. Two and a half miles south by east of Kanbauk (19° 53′ ; 94° 37′) in the stream east of Zindaw village (19° 52′ ; 94° 38′) a thin seam of impure coal and carbonaceous shale dips 15° E. 10° N. in blue shaly sandstone, but owing to the thick soil cap the relations of these rocks cannot be determined.

From Manaung on the Kanni road (19° 51′ ; 94° 39′) after crossing the foraminiferal limestones, dips, where seen, are discordant and the rocks consist of fawn sandstones, blue shaly strata and occasional shelly sandstones.

Sequence in main range south of Tabingyo.

From Tabingyo south-westwards, the shales underlying the Eocene-Pegu boundary foraminiferal band are succeeding by an alternating series of sandstones and shales on the same N. 15° W. strike in which a little fossil wood is present. A shelly coal conglomerate occurs as lenticles in shales 250 yards south-west of Tabingyo and contains *Ostrea* fragments ; limy bands also occur in the alternating series.

Upper-most Eocene sequence : Myegya.

To the south-south-east, the Kyet-u-bok—Tabingyo band occurs as a ferruginous foraminiferal conglomerate in the *nala* one and a quarter miles due west of Myegya and is about five feet thick. In other limy bands which occur above it I noticed no foraminifera, but lower in the sequence about 300 yards to the west, was another band 18″ thick containing foraminifera and corals. In the southernmost tributary of the same stream on the same line of strike, a limy conglomerate containing foraminifera and broken shell fragments dips E. 25° N. at 30° and is underlain by shaly strata in which a similar band occurs about 80 feet lower in the sequence. These limestone conglomerates are overlain by soft bluish sandstones, sometimes shaly and sometimes limy and hard.

In the same *nala* one and a quarter miles W. S. W. of Myegya (19° 53′ ; 94° 44′) a fragmentary fossil band occurs in massive sandstones, whilst a little further to the west, occur ferruginous and fossil conglomerates underlain by a quartz conglomerate. Following this are blue shales passing into soft sandstones to the Thonmyezon (19° 53′ ; 94° 43′)—Kandok Road (19° 50′ ; 94° 43′). From here to the west an alternating series of sandstones and shales weathering into scarp and dip slopes occurs.

Sequence: Myegya-Kandok Road.

Practically the same series is seen further south on the Myegya-Kandok Road. Two and a half miles south by west of Myegya the uppermost Eocene horizon occurs as a foraminiferal limestone band six feet thick and dips N. E. by E. at 34°. It contains :—

Orthophragmina (*Discocyclina*) *omphalus*, Fritsch.
Orthophragmina (*Discocyclina*) *sella.*
Gypsina globulus.
Operculina canalifera.
Nummulites yawensis.
Ostrea sp.

This band is overlain by shales and forms a marked dip slope to the north where But *chaung* meanders along its eastern flank.

About half a mile to the west of this band the shelly and quartz conglomerates, noted in the *chaung* further north, are encountered, whilst further west towards Kandok fawn coloured sandstones dip N. E. by E. at 21°, and have limy fragmentary fossil bands towards their base.

Fault north of Ngamyin-U (19° 49′ ; 94° 45′).

To the south from the Myegya-Kandok road the upper foraminiferal limestone band of the Eocene can be followed in a S. 25° E. direction for about 600 yards before it becomes lost in the soil cap. A cross fault then appears to displace it to the east as it is next seen as a thin band 8″ thick in the *nala* one and a quarter miles N. W. by N. of Ngamyin-U (19° 49′ ; 94° 45′) and again in the *nala* immediately east of the same village where the following forms were collected :—

Orthophragmina (*Discocyclina*) *sella.*
Gypsina globulus.
Operculina cf. *canalifera.*
Nummulites sp.

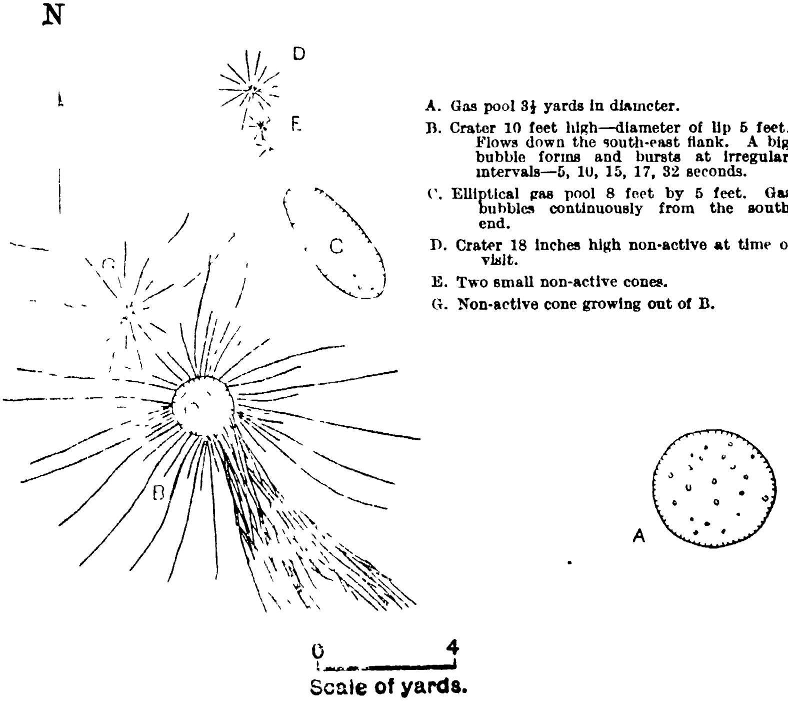
One and a half miles south-east of Ngamyin-U the same fauna occurs in a thin (2″) band in shales which underlie sandstones containing *Volutoconus* sp., *Lucina* sp., *Cytherea* sp., *Cardium* sp. and *Cardita* sp., and again one mile north-west of Thabyemyaung where *Orthophragmina* (*Discocyclina*) *omphalus* also occurs. An alternating sandstone and shale series from 6,000-7,000 feet thick underlies this boundary band and dips north-east at about 30° ; the base of this series consists of softish sandstones and forms the Kandok—Tonaing (19° 46′ ; 94° 45′) ridge.

Further south where the Minhla-Myothit (19° 45′; 94° 40′) road crosses the Upper Eocene rocks, folding and crushing has made the stratigraphical relations more complicated. Of this area Dalton[1] notes—

Dalton : Minhla-Myothit Road.

> 'The easterly dips continue for some three miles west of Thabyemyaung (19° 47′; 94° 48′) and then, after an increase in angle through 35° and 50° to 69°, the beds turn over to south-west at angles of 69° and more, the rest of this anticline being marked by hot springs and mud volcanoes.
>
> From near the crest in this locality an impure ferruginous limestone was obtained full of shells of *Turritella* sp. 3.'

Rao Bahadur Sethu Rama Rau who visited this area during the 1909-10 field season failed to find the anticlinal structure mentioned by Dalton. An anticline does, however, occur although it is very faulted and in the vicinity of the mud volcanoes of Yegubwet (19° 46′; 94° 47′) (Plate 15 and figure 2) the western limb has



A. Gas pool 3½ yards in diameter.
B. Crater 10 feet high—diameter of lip 5 feet. Flows down the south-east flank. A big bubble forms and bursts at irregular intervals—5, 10, 15, 17, 32 seconds.
C. Elliptical gas pool 8 feet by 5 feet. Gas bubbles continuously from the south end.
D. Crater 18 inches high non-active at time of visit.
E. Two small non-active cones.
G. Non-active cone growing out of B.

FIG. 2.—Plan of mud volcanoes and gas pools, Yegubwet.

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[1] *Ibid*, p. 611.

been cut out by this faulting. South-eastwards along the range the structure is more clearly seen and further mud-volcanoes and gaspools (figure 3) enable one to delineate the line of faulting.

Thabyemyaung : Coal.

One mile south by west of Thabyemyaung, massive false-bedded sandstones with occasional alternating sandstones and shales dip north-east at 36°. Along the *nala* to the south the dips steepen quickly to 65° into predominantly shaly strata containing carbonaceous bands and thinly bedded coal shales, resin occurring in association with the coal. At the base of these shales there is a band of *Ostreæ* from 18 inches to two feet thick; in the stream bed the cementing sand has weathered away and hundreds of good specimens can be picked up. This shaly series characterised by oysters is underlain by massive sandstones in which *Ostreæ* also occur and which form the summit of the range; from the summit a magnificent view is obtained of the main Yoma chain to the west.

When working in this area Mr. Sethu Rama Rau regarded the foraminiferal limestone band at the top of the Eocene as of Oligocene age as he recognised only *Operculina* in it whilst Vredenburg had identified the *Ostreæ* which he had collected from below this band as *Ostreæ longirostris*, Lamarck an Oligocene form. There is however no doubt of the Eocene age of the upper horizon. From a fossil band below the limestone Mr. Rau collected :—

Triton sp.
Ampullina grossa.
Lucina sp. cf. *Pagama.*
Pyrula sp.

On the Myothit-Minhla P. W. D. road west of Thabyemyaung only the sandstones of the series are seen. The dips in these are steep one and a third miles W. S. W. of the village and from there onwards to the west for another mile, but after that, the normal dip and strike seen further north is resumed.

Mud Volcanoes : Yegubwet.

Two miles south-west of Thabyemyaung in the vicinity of the mud volcanoes and gas pools massive blue false-bedded sandstones with very discordant dips occur. Although faulting has taken place and becomes obvious further to the south, it is not perceptible on the ground. The mud volcanoes and gas pools bring up blue mud similar to those of Minbu and there is a strong petroliferous smell over the whole area.

Thonmyezon area.

South-east by south of Thabyemyaung only debris of the characteristic upper band of the Eocene was found; east of Thonmyezon (19° 45′; 94° 49′) occur a series of carbonaceous shales reinforced by sandstones and with thinly bedded coal seams: they dip E. 30° N. at 45° and are overlain by massive sandstones which form a ridge at the base of the Pegu series; towards the base of these massive sandstones occurs a very characteristic ferruginous fine-grained grit containing comminuted shell fragments and small corals. The same band was seen to the north-west near Kyaukpon (19° 50′; 94° 46′) where it was over three feet thick and very persistent.

Faulting has taken place in the series and east of Thonmyezon a small thrust was noted. About five furlongs S. E. by E. of Thonmyezon, a thin band of foraminiferal limestone occurs on the Thonmyezon-Gwegyaw (19° 44′; 94° 52′) track, and in the neighbouring *nala* at approximately the same horizon in a hard shelly limestone *Volutoconus* sp. and *Corbula* sp. were noted. The series dips north-east at 35°.

Eocene foraminiferal bands: Kyangan *chaung*.

Eocene boundary bands were picked up again on Kyangan *chaung* one and a half miles south-east by south of Gwegyaw, where a lower one contains *Gypsina globulus*, *Nummulites yawensis*, *Operculina* sp. and *Orthophragmina* (*Discocyclina*) *sella*. It is only about 8″ thick and is overlain by massive sandstones. About 50 feet from the base of these massive sandstones is another Eocene foraminiferal band containing the same assemblage; it passes upwards into a shaly intercalation of the sandstone series. These sandstones which probably correspond to the Shwezetaws of the Man *chaung* area form a pronounced ridge on a N. 30°-35° W. strike; hard sandstones pass up into softer blue and brown banded ones which are inclined to be shaly, and these eastwards into alternating sandstones and shales. The series is however predominantly sandy.

Below the foraminiferal limestones the Upper Eocene sequence is shaly; contortion in these shales is common as also are carbonaceous patches; faulting also occurs. The shales are underlain by soft sandstones which dip north-east at 60° and the latter by another shaly band in which oysters, similar to those found west of Thabyemyaung further north, are common. Massive sandstones form the summit of the range.

Discordant strata west of Kanywa.

Three miles to the south-west, folded shaly strata make up the summit of the range; in this series dips are very discordant and vary from low to steep angles W.S.W. and E.N.E. They are overlain two and a quarter miles W.S.W. of Kanywa (19° 42′; 94° 55′) by sandstones containing—

Cardium thetkegyinensis.
Ampullina sp.
Corbula sp.
Ostrea sp.
Tellina sp.
Pinna sp.
Corals.

Some three hundred yards along the scarp below the base of these fossiliferous sandstones is a conglomerate containing siliceous pebbles which dips E. 35° N. at 63°. Overlying it are sandstones which pass upwards into shales with carboncaeous patches and fawn-coloured sandstones. On the road one and a half miles W.S.W. of Kanywa a ferruginous band was met containing nummulites and *operculina*, and a similar band a few hundred yards to the E. S. E. These last occurrences are not on the line of strike of the uppermost Eocene horizon mapped further north; perhaps strike faulting oı small cross faults have been responsible for the transposition. Faulting has certainly occurred.

Broken anticline of main range west of Singaing.

To the south by east, discordant dips on a N. N. W. strike are found in the fawn sandstones exposed two and three quarter miles west-south-west of Singaing (19° 40′; 94° 57′), whilst further west the rocks forming the summit of the range dip W. S. W. at from 30°-40°. In the stream bed to the north of Pt. 1002 contorted carbonaceous blue shales occur on a N. 20°-30°W. strike; these shales are reinforced by sandstones which are occasionally strongly ripple-marked; seven furlongs south by west of Pt. 1210 a vertical *Ostrea* band was seen striking N. 30° W. across the *nala*. This contorted series occurs for over a mile eastwards down-stream and is followed by blue shales dipping north-east. No distinctive Upper Eocene fossil band was found in this section but further to the south about half a mile south-south-west of Kyauktaga (19° 36′; 94° 56′), *Operculina*, *Nummulites* and *Volutoconus* occur at the top of the more westerly of two massive sandstone bands.

Upper Eocene Series west of Talokyin.

Massive sandstones, bluish when fresh, form the ridges a mile west by south of Talokyin (19° 34½′; 94° 57′) and are separated by a shaly series reinforced by vertical sandstones on a N.—S. strike. Below these are a series of sandy shales in which thin shaly coal seams all very badly crushed occur. This coal is underlain in one place by ripple-marked sandstones dipping 85° E. 5° N.; the ripple-marks face west so that overfolding must have occurred. The reinforced shale series continues up to the summit of the range in this section. To the south-east, Eocene foraminifera occur in the massive ferruginous sandstones which dip north-east at 50° on the 'col' over which the track from Talokyin climbs on the way to Tiyo (19° 32′; 94° 57′). Westwards between here and Kywegan (19° 33′; 94° 55′) an alternating series of rocks in which sandstones predominate are found; on the east of the watershed the rocks generally dip east, and on the west side, west; strike faulting appears to have taken place along the axis of the anticline into which the range is folded.

Hills west of Paungganaing.

West of the Paungganaing (19° 29′; 94° 57′)-Pungyi (19° 27′; 94° 57½′) valley to the south, Eocene foraminiferal limestone is found occurring in the higher parts of the ridge and the face of its eastern slope, the rock dipping at a high angle east-north-east; to the north by east, one and a quarter miles north-west of Paungganaing, this band dips 30° south-east and is only 18″ thick. The limestone occurs intermittently, capping the ridge to the south-east, until the ridge terminates in confused hilly ground three miles north by west of Kyaukkyi (19° 20′; 94° 59′). Two miles north by west of the latter place, a similar limestone is found dipping south at the village of Konkyaukkyi (19° 22′; 94° 59′), but from this latter place it swings to the north-west and forms a conspicuous ridge for over two miles increasing in thickness from eight feet, where seen on Kyaukkyi *chaung*, to 50 feet on Kyauk *chaung*.

Southerly pitch of Eocene anticline north of Kyaukkyi.

The core of the anticline so formed consists of very much broken and faulted sandstone and shaly strata; the latter predominates on the flanks and is characterised by thin seams of coal and carbonaceous shales. The general strike of the anticline is N.W.-S.E. changing to N.-S. towards the north. The dips of the rocks, in general, correspond with this strike, but, as will be seen from the map, vary very considerably in angle. This is, of course, due to the considerable amount of faulting that has taken place. At the south-eastern end of the range where the Eocene rocks pitch out, dips to the south-east and south are common, and east by north of Konkaukkyi a thin band of foraminiferal limestone dips 60° S. by E. and is overlain by soft sandstones. Eastwards from here shaly strata grading into sandstones and weathering spheroidally are seen along the path to Didubin (19° 23′; 95° 0′) and also to the south of the latter village.

Synclines: West of main Eocene range.

West of this main range occurs a syncline and on the flanks in the hollow of this syncline further Eocene limestones are exposed. Above these limestones at Mibauk (19° 27′; 94° 53′), north of Gwedauk (19° 29′; 94° 54′), and further north in the Shandat forest reserve are a series of unfossiliferous strata which I have regarded as forming the base of the Pegu System. Faulting is very common in these boundary rocks; the foraminiferal limestones are very intermittent in character; the forest and soil cap are thick and communications poor. Moreover, the limestones are very inconsistent in their occurrence, and in some places, although the summit of the ridge is made up of foraminiferal limestone, its bedding planes are found to strike at an angle with the direction of the ridge. Normal faulting also occurs in the hollow of the synclines and there is a general sameness of both basal Pegu and Upper Eocene strata. The Eocene boundary has therefore been interpolated to include only strata in which Eocene foraminifera occur.

The following sequence was obtained in the Sibon *chaung* near Mibauk in descending order:—

Mibauk syncline.

(1) Fawn sandstones.
(2) Bluish sandy shales.
(3) Massive bluish foraminiferal sandstones fawn on weathering.
(4) Alternating sandstones, shales and Eocene foraminiferal strata.

These divisions could be recognised in a general way in the synclines to the north; the top two divisions do not contain Eocene foraminifera and have been regarded as of Pegu age.

CHAPTER VIII.—DETAILED DESCRIPTION OF ROCKS: UPPER EOCENE STRATA WEST OF THE MAIN RANGE AND SOUTH OF LATITUDE 19° 45′.

Myothit area.

East of Myothit (19° 45′; 94° 40′) the main range consists of soft fawn sandstones with dips which become discordant in a westerly direction, and it is very probable that a fault occurs hereabouts *en échelon* with that along which the mud volcanoes and gas pools occur to the south-east. A shaly series underlies this sandy one giving rise to massive fine-grained greenish sandstones forming the scarp slope which runs N. 30° W. from immediately east of Pyindaung village (19° 46′; 94° 43′). West of this scarp the dips become very discordant again, and a fault probably occurs running parallel to and immediately west of the scarp. Along the Myothit-Minhla road to the west, the strata then dip S. 30° W., and in Kadok *chaung*, just south of the road, occur as an alternating series of efflorescent sandstones and shales, the sandstones having shaly partings.

Coal : Zaigyi.

At Zaigyi (19° 44′; 94° 41′), one and a half miles south of Myothit on Pani *chaung*, there is a small exposure of coal in a series dipping E. 25° N. at 20° in a further area of discordant dips. A band of lignitic sandstones two feet thick containing chunks of coal up to 18″ in diameter, are overlain by sandstones, the junction being irregular; they are underlain by five feet of carbonaceous shales, at the upper surface of which are stringers of coal eight inches thick and up to two yards long.

The coal is apparently drift material, as the highly carbonaceous sandstones above, though coarse, are homogeneous. Economically the coal is useless.

Shandat Reserved Forest.

East of Yengan (19° 44′; 94° 45′), in the syncline which runs S. S. E. through the heart of the Shandat forest reserve, pale greenish, soft, efflorescent sandstones, with occasional shale bands, weather spheroidally and lie either horizontal, or dip at low angles to the north-east or north-west. Thin Eocene foraminiferal bands bound these sandstones on the east and west; that on the west, just over a quarter of a mile east of the village, dips north-east and that on the east, which occurs near the fault which flanks the syncline, strikes N. 10° W. and is vertical. South of Yengan, soft greenish efflorescent sandstones are found west of Ngahlaing (19° 42′; 94° 47′) and at Sangyi (19° 41′; 94° 47′) dipping E. N. E. at low angles, they are underlain by more heterogeneous sandstones, some of which are gritty and calcareous. In all these sandstones, Eocene limestones containing *Discocyclinae* and nummulites are developed; they cap the hill of Tun-taung (19° 43′; 94° 41′) (Pt. 1009) and, further to the west, the Pt. 997 ridge. In this latter ridge the limestone forms a continuous exposure about one mile long and contains *Orthophragmina* (*Discocyclina*) *Javana*, *Orthophragmina* (*Discocyclina*) *omphalus* and *Orthophragmina* (*Discocyclina*) sp. Many small exposures of limestone also occur; immediately north of Sangyi village two bands of foraminiferal limestone dip E. 20° N. at 27° and a 40 feet water fall is formed by a hard fossiliferous band containing nummulites underlain by soft fine-grained fawn sandstones.

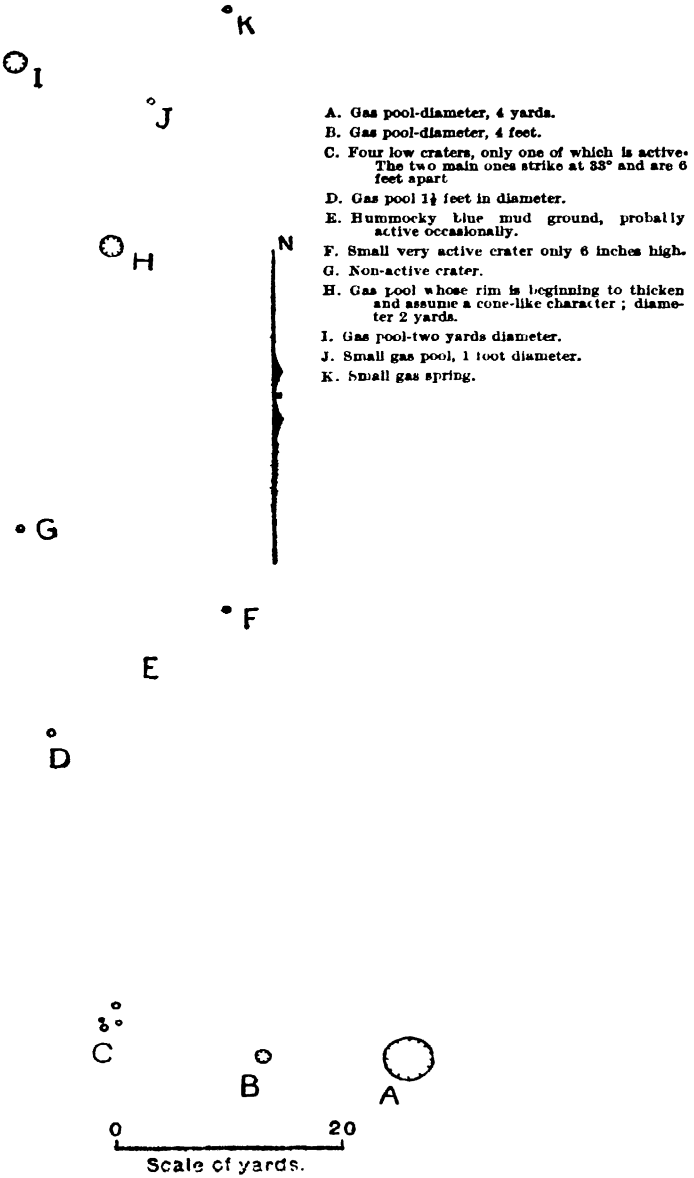
Sangyi : Gas pools.

Three and a half miles E. N. E. of Sangyi is an occurrence of gas pools and mineral springs arranged in the manner shown in Figure 3. This occurrence, combined with that of Yegubwet to the north, and the steep discordant dips of the strata, give the line of faulting on this eastern flank of the syncline. Eocene limestones and sandstones are found to the west of the fault practically as far as the stream junction three miles E. N. E. of Sangyi. The intervening country to Sangyi is composed of soft greenish efflorescent horizontal sandstones through which the streams have cut down in a series of meanders; cliff sections occur in the concavities of their innumerable bends. Away from the streams, the soil cap is very thick and little can be made of the geology between Sangyi and Shandatkyi (19° 37′; 94° 45′) to the south by west.

Shandatkyi.

South-west of Shandatkyi the country is undulating, very dissected, and has a very thick soil cap. The Pani *chaung* valley at Taungdaw (19° 35′; 94° 43′) is weathered out of homogeneous sandy shales and fine-grained sandstones which are overlain half a mile north-west of Taungdaw by massive sandstones forming the 981 ridge. Two miles north-east of Taungdaw, a conglomerate containing *Ostreae* dips E. N. E.

Four miles south by east of Shandatkyi, the Pani *chaung* breaks eastwards through alternating soft sandstones and reinforced shales



- A. Gas pool-diameter, 4 yards.
- B. Gas pool-diameter, 4 feet.
- C. Four low craters, only one of which is active. The two main ones strike at 33° and are 6 feet apart
- D. Gas pool 1½ feet in diameter.
- E. Hummocky blue mud ground, probably active occasionally.
- F. Small very active crater only 6 inches high.
- G. Non-active crater.
- H. Gas pool whose rim is beginning to thicken and assume a cone-like character; diameter 2 yards.
- I. Gas pool-two yards diameter.
- J. Small gas pool, 1 foot diameter.
- K. Small gas spring.

FIG. 3. Plan of gas pools and mud volcanoes, half a mile south of Pt. 1485 (19° 42: 94° 47′).

which dip east by north at angles of from 20°-30°. In some of the fine-grained rocks of this series half a mile north of Pt. 788, there is a spring which smells strongly of hydrogen sulphide.

Ostreae, similar to those seen west of Thabyemyaung, characterise these alternating strata from Auklege (19° 33′ ; 94° 49′) to half a mile west of Gyogyagon (19° 34′ ; 94° 50′), where massive fine-grained sandstones form the centre of the syncline.

Immediately west by north of Kangyaw (19° 36′ ; 94° 50′) in the Taung-wun *chaung* a band containing *Orthophragmina* (*Discocyclina*) *omphalus*, *Orthophragmina* (*Discocyclina*) sp., nummulites and fragmentary molluscs was noted.

Kangyaw area.

Compact sandstones alternate with softer ones with shaly partings for about two miles east by north from Kangyaw, until an Eocene limestone is encountered. Soil cap then obscures the geology to immediately west of Nyaungbintha (19° 37′ ; 94° 53′) where sandstones dip W. S. W. at 24°. East of Nyaungbintha, high discordant dips occur in an alternating sequence of shales and sandy rocks, the latter occasionally flaggy and rather similar to those occurring further east on the eastern flank of the range.

Pani *chaung*: South of Gyogyagon.

South-south-eastwards from Gyogyagon down the Pani *chaung*, the strata are all fairly horizontal, and consist of fine-grained sandstones as far as Yathaya (19° 33′; 94° 52′), where, immediately south of the village, an Eocene foraminiferal limestone six to eight feet thick dips south at a very low angle across the river. Overlying this band are 60 feet of horizontal fine-grained shaly sandstones, in which harder foraminiferal lenses weather out. These sandstones form the cliffs at the bend half a mile south by east of Yathaya and are found along the stream to the south to one mile north-west of Taungyan (19° 31′ ; 94° 52′), where a harder series overlies them and dips south by west at 8°.

West of this reach of the river, soft fawn sandstones, with occasional sandy shales, harder nodular limy bands, and foraminiferal limestones, dip eastwards at angles which increase to 60° as one approaches the Nabedaung (19° 32′ ; 94° 49′) ridge to the west. Contemporaneous conglomerates included in the series contain foraminifera in the matrix, and the whole form a series of scarp and dip slopes culminating in the steep scarp of the main ridge.

Limestone band: Sadwin-Pani *chaung* junction.

Five furlongs north-west of Taungyan, where Sadwin *chaung* joins the main stream an algal foraminiferal limestone band 12 feet thick dips S. S. E.; it is twice repeated by small faults on an E. 40° N. strike. This band contains the following fauna :—

Operculina canalifera.
Orthophragmina (*Discocyclina*) *omphalus.*
Nummulites yawensis.
Discocyclina sp.
Schizaster sp.

Bluish fine-grained shaly sandstones, with occasional foraminiferal lenticles similar to those seen in the main stream further north, are found to the eastwards to Kywegyan (19° 33′; 94° 55′), and also form the hill of Trigonometrical Pt. 693, immediately north of Taungyan, which is capped by sandstones weathering in columns.

Gwedauk syncline.

South down Pani *chaung* to Gwedauk (19° 29′; 94° 52′), similar fine-grained sandstones, occasionally grading into shales, give good cliff sections. Dips are low, except at the termination of the eastern reach one and three quarter miles S. E. by E. of Taungyan, where the rocks dip fairly constantly at about 40° S. W. and W. S. W.; foraminifera occur sporadically in them.

South from Gwedauk, soft fine-grained sandstones with harder lenticles and, occasionally, banded calcareous strata, shales and thin bands of Eocene foraminifera, dip at low angles, and are intersected by transverse faults. One mile north by east of Mibauk, a small anticline striking N. 35° W. is overlain to the south by fawn sandstones. From sandstones to the east of the anticline the following were collected :—

Orthophragmina (*Discocyclina*) *sella.*
Nummulites yawensis.
Volutolithes sp.
Oliva sp.
Discocyclina spp.
Corals.

Mibauk syncline.

One and a half miles E. N. E. of Mibauk, foraminiferal limestones dip W. 25° S. at 43°; to the east the strata are horizontal to where the Mibauk-Paungganaing road crosses Kyaukchaw *chaung*. Here a fault strikes N. 12° W.

and the strata are all vertical. One mile further to the east, low dips to the north and east prevail in fawn sandstones, and mark the centre of the anticline, as, to the north-east, alternating massive sandy strata dip due east at angles of about 65°, flatten to 30°, and then steepen again after the watershed is crossed.

The last-mentioned fault was picked up over a mile to the north, half a mile east of the 234-805 foraminiferal limestone ridge. To the east of the fault, alternating sandy and shaly strata dip to the east.

Sibon *chaung*.

North-west from Mibauk up Sibon *chaung*, the soft massive fine-grained sandstones of the Mibauk basin are underlain by blue shaly sandstones or sandy shales, in which, at the base, occur stringers of coal and resin ranging over a depth of 18″. Higher up the *chaung*, two miles north-west by west of Mibauk, a hard shelly band in the shales contains the following :—

Lucina yawensis.
Cardium Kanleanum.
Natica sp.
Capulus sp.
Turritella sp.
Ceritheum sp.

A little lower in the sequence the big Pondaung *Ampullina* and an *Ostrea* was collected. Westwards, massive brownish sandstones dip due east, and are underlain by a harder more limy series of sandstones and the latter by a hard fine-grained greenish sandstone forming the 829-912 ridge (longitude 94° 50′). Still further west, similar rocks, in which occurs a pool smelling strongly of hydrogen sulphide, pass down into alternating hard and soft sandstones; these continue to the summit of what has now become the main range east of the Arakan Yomas.

Limestones South-west of Mibauk.

From west to south of Mibauk, Eocene limestones are strongly developed; they dip in a north-east direction in a similar series of rocks to that of Sibon *chaung*. In the Sibon *chaung*, no prominent foraminiferal limestones were seen although occasional Eocene foraminifera were found in the shaly sandstones. Westwards between Mibauk and the Yegyansin (19° 22′; 94° 52′)—Sangyi (19° 27 ; 94° 47′) road, two foraminiferal limestones are present, the most easterly forming the very prominent 762-1034 ridge, which at places, notably to the north, attains considerable thickness, and the second which occurs as a thin discocyclinal band, a third of a mile N.-E. by N. of Mile 38 on the Sangyi-Yegyansin Road. About 200 feet below this latter, an isolated exposure of fossiliferous sandstone was noted containing the Pondaung sandstone *Ampullina.* Westwards from here, the series is sandy to about Mile 41, where the Yegyansin-Sangyi road cuts through the main hill range, and here shales reinforced by soft sandstones prevail.

South from Mibauk three main limestones are met with. The first one, just over a mile south of Mibauk, dips 23° N. 33° E., has a thickness of about 105 feet and contains *Operculina* sp. and *Nummulites yawensis.* It is overlain by an alternating series of hard and soft sandstones which become massive to the north and in which, where Kyaukpyok *chaung* joins Sibon *chaung*, 50 feet of blue shales occur. Below the limestone is an alternating series of shales and sandstones, the former predominating at the top immediately beneath the limestone. These pass down into the second big limestone band where a fault occurs striking E.-W. along the Kyaukpyok *chaung.* The strata on the south side of the stream have been let down about 50 feet by the fault. This is the limestone band which forms the prominent 762-1034 ridge to the north, and contains—

Operculina sp.
Orthophragmina (*Discocyclina*) *Javana.*
Orthophragmina sp.
Nummulites sp.

Where the band thickens to the north-west, the bedding strikes at an angle to the line of the ridge. The third big limestone band forms Tondaung *Taung* (Pt. 1065—19° 25′; 94° 52′), three miles south of Mibauk, and passes eastward into soft fawn sandstones in which small lenticles of limestone are developed. Another small lenticle of limestone is developed one mile due south of Pt. 1065 near to Hmoktalon village (19° 24′; 94° 52′).

The Pani *chaung,* from Mibauk to the south, passes through soft blue shaly sandstones which contain occasional foraminiferal horizons; they are either horizontal or dip at low angles, and are occasionally capped by a harder sandstone band forming cliffs up to 100 feet in height. Small faults are common and red earth and gravels are also sometimes found on the surface of the series. In the Taungpila *chaung*, which enters the Pani *chaung* at Magyiyaw (19° 26′; 94° 55′), discordant dips and fracturing occurs in this sandy series which dips west by south and a series of faults strikes N. 10° W. Further to the east, one and a quarter miles north-east of Magyiyaw, reinforced shales form the core of the main anticline.

On the Thayetmyo (19° 20′; 94° 14′)—Mindon (19° 21′; 94° 46′) road a foraminiferal limestone band caps soft Eocene sandstones at Mile 28·2 (the limestone is quarried for road metal on Hill 730 to the north). The ridge which is formed by the limestones continues to the south, possibly being stepped back to the east by a small fault just south of the road, to the rather isolated hill a quarter of a mile due south of Mile 28·3. From this latter point to immediately east of the stream junction, two miles due east of Thayetsan, (19° 21′; 94° 50′) limestone can be followed intermittently along the ridge. There are fairly big exposures where, now and again, the dip slope of the limestones corresponds to the slope of the hill. The dips of the limestone increase from 30° E. by N. on the P. W. D. road, to 60° less than a mile to the south, and then remain fairly constant to Yaw *chaung*, where two bands occur, one to the east and one to the west of the stream junction two miles east of Thayetsan.

Yegyansin (19° 22′; 94° 50′).

Westwards from Mile 28·2 on the Thayetsan-Mindon P. W. D. road the strata are rather shaly, but give rise after Mile 28·4 to a series of alternating sandstones and shales in which the sandstones are rather flaggy and occasionally fossiliferous. These are succeeded by a series of sandstones, strongly false-bedded, and in places approximating to a collection of lenticles, until a thin band of foraminiferal limestone is reached at Mile 29·3. They then pass into an alternating series of sandstones and shales followed by false-bedded sandstones with alternating harder bands and dip from 20°-30° east of north at from 20°-30°.

This series, which continues to Yegyansin, is better exposed in Inbyit *chaung* to the north, where the lower limestone band, half a mile west of Inbyit (19° 23′; 94° 52′) village, attains a thickness of 12 feet, and contains—

Upper Eocene Series: Inbyit *chaung*.

Pecten sp.
Orbitoides sp.
Nummulites sp.

Just below the upper limestone band in the *chaung* half a mile E. S. E. of the same village a sandstone contains—

Cardium sub-fragile.
Volutoconus birmanica.
Oliva sp.
Rimella sp.
Cytherea sp.

At Yegyansin bungalow (19° 22′; 94° 50′) these soft fawn sandstones with harder bands dip north-east at 70°. They continue to the west and at Miles 31·3 and 31·6 contain thin ferruginous bands with fragmentary lamellibranch detritus. Fine shaly sandstones, dipping N. E. by E. at about 20° continue to the east, and in these at Miles 32·1, 32·5, 33·1 Eocene *Discocyclinae* were noted.

In the stream south of Mile 33·2, a good section of about 100 feet of fine sandy shales can be seen, whilst blocks of ferruginous conglomerate in the stream contain a mixture of Eocene *Discocyclinae*, broken molluscs—*Turritella* sp., *Tellina* sp.—and corals. Further upstream, a quarter of a mile south-east of Mile 33, fine shaly sandstones with coarser false-bedded lenticles dip north-east at 22°, whilst to the south-east, on the ridge which carries the Thayetsan-Mindon road, occurs a rather ferruginous fossiliferous sandstone. This sandstone is overlain further east by soft sandstones with intercalated efflorescent bands and dips N. E. by N. at about 20°. Interbedded in these latter sandstones, which become more shaly higher in the sequence, is a six-inch band of ferruginous conglomerate made up of Eocene foraminifera and ferruginous concretions. This conglomeratic band is probably continuous with a band from which Eocene foraminifera found in the east bank of the stream north-east of Thayetsan are derived. The same fauna is contained in it *viz.*, *Discocylina omphalus*, *Discocyclina* spp. and a large nummulite.

From Yegyansin, the fine-grained sandstones with harder limy lenticular bands, some of which attain a hundred feet in thickness, continue to the south-east by south and form the ridge which runs parallel to the uppermost Eocene limestone band just over a mile and a half to the east. Half a mile N. 30° E. of Thayetsan foraminifera occur in this series, whilst down the short cut to Thayetsan from this point and about 200 yards nearer to the village, the soil cap is strewn with a variety of forms in the high bank on the north side of the stream. Up the path on the south side of the stream, big specimens of *Discocyclina Javana* are found on the road; they may, however, be derived from the stream below, as the villagers of Thayetsan use the bed of the stream as a source of road metal, and at the time of my visit one could pick up large medallion-like forms of *Discocyclina* all along the village street.

Thayetsan : 19° 21′ ; 94° 50′.

From Thayetsan westwards along the Kyingyi (19° 19′ ; 94° 48′) track specimens of *Discocyclina* occur 200 yards south-west of the village in fine-grained sandstones; further to the west, stringers of calcite occur in a very indeterminate series. Thence, up the hill, occur soft sandstones with harder ferruginous lenticles, the ferruginous partings occasionally showing traces of fossils. One dip of 75° E. by N. was registered although 30° E. by N. was the general one. The bedding of this series was difficult to see owing to the debris derived from the precipitous scarp above, where dips in the fine sandstones with occasional harder bands are 30° W. by S. West of the line of calcitic stringers no Eocene foraminifera were noted and the line of a strike fault is probably indicated, the Thambula reserved forest to the west forming the eastern flank of a syncline.

East of Thayetsan, to the west of the Yegansin road junction, remnants of a ferruginous conglomerate containing *Discocyclina* were noted and can be correlated with the occurrence about three quarters of a mile N. W. by N. of Thayetsan. East of the road-junction aforementioned, two bands of fossiliferous shaly strata occur; the first shows a preponderance of large foraminiferal forms, and the second, one hundred yards to the east, of small forms. These bands appear to be a continuation of the ones noted on the high north bank of the stream a quarter of a mile north-east of Thayetsan.

Upper Eocene sequence Yaw *chaung*.

In the Yaw *chaung*, three quarters of a mile east of Thayetsan village, the Eocene series consists of bedded, bluish, fine-grained, and slightly micaceous sandstones, the bedding ranging from inches to a foot in thickness and dipping north-east at 27°. Sometimes these sandstones are rather flaggy and at others contain limy concretions, whilst one and a half miles due east of Thayetsan, a thin band (1 foot) of foraminiferal limestone occurs. About 300 yards further east, a harder fossil band was found to contain a mixed assemblage of foraminifera and molluscs. Among the molluscs *Velates* sp. was doubtfully recognised. The dip hereabouts is north-east at 35° steepening further east to 40° in a series of massive fawn sandstones (cinnamon coloured when wet) with occasional concretionary lenticles, efflorescent bands, and fragmentary fossil horizons. Harder bands in the soft series dip N. E. by E. at 45° and occur to the east; they are succeeded by a band of foraminiferal and concretionary limestone two feet thick which dips N. E. by E. at 60°. This latter, which contains nummulites and various species of *Discocyclina*, including *Discocyclina omphalus*, is followed by more massive soft bluish efflorescent sandstones with occasional shelly conglomeratic bands, from which a large species of *Ampullina* cf. *grossa* (Dalton) was collected. They persist to the stream junction two miles east of Thayetsan, where the most easterly limestones of the Thayetmyo-Mindon P. W. D. road cut across the *chaung*. The latter are here of a concretionary nature, have a thickness of 70 feet and dip E. 20° N. at 21°. Joints in the limestones run N.-S. Shales succeed the limestones to the east to beyond the next big stream junction, and then pass into shaly blue sandstones, which continue to the spur which runs south-west from Mile 25·4 on the P. W. D. road. On this spur quartzitic gravels are to be found.

From Thayetsan, to the south-east along the Thakutkyaw (19° 18′; 94° 54′) road, *Discocyclinae* are found on the track just over one mile from the village first named, and are derived from a ferruginous band in soft fairly fine sandstones dipping 40° N. E. Further to the south-east, odd specimens can be picked up on the road apparently from the same fine, sandstone series. On the north side of Yaw village (19° 20′; 94° 52′) innumerable specimens occur in the *nala* in soft bluish shaly sandstones, shales, and ferruginous concretionary bands, occasionally efflorescent, which dip north-east at 50°. Shales with harder sandy ferruginous lenticles dip N. E. by E. at 80° in the more southerly of the two Yaw villages, whilst *Discocyclinae* are found on the Thambula (19° 18′; 94° 53′) road three quarters of a mile to the south-east by south, and are derived from similar thin conglomeratic bands. They continue intermittently to Thambula, where they are found in quantity in the rocks underlying the village. This group of fine shaly sandstones, with thin intermittent foraminiferal conglomeratic and shaly bands, can be traced practically continuously from Mile 33 on the Mindon Road to Thambula, a distance of six miles; they underlie a broken line of paddy fields.

Yaw-ywa (19° 20′; 94° 52′).

One and a quarter miles east of Yaw village, the Pegu-Eocene boundary limestone appears to be about 30 yards thick, but it is difficult to say, as, occurring in a softer series of rocks, it breaks down along the joints into blocks, which obscure the junctions. Below the limestone are soft fine alternating sandstones and shales; above are shales. From this point, eastwards along the Ale-chaung (19° 22′; 94° 54′) road for half a mile, odd lumps of concretionary foraminiferal limestone were found but not being *in situ* were judged to be transported material.

Thakutkyaw: (19° 18′; 94° 54′).

From Thakutkyaw, for a mile to the south, all the rocks seen consist of vein calcite and pieces of fine sandstone, obviously derived from sandy lenticles in a shale series. Up the steep ascent along the Natmauk (19° 16′; 94° 52′) track, south-westwards from a point one mile south of Thakutkyaw, fine fawn sandstones dip S. W. by W. but exposures are very much obscured by debris. On the summit only small pieces of fine fawn sandstone with carbonaceous markings occur, but to the south-west, down the slope, sandstones with occasional shaly bands dip 50° S. W. The dip slopes down which the track passes are very steep and in the streams one finds a succession of water-falls where the harder bands, some of which attain a thickness of 150 feet, cross. At the more westerly forest boundary, the fine sandstones pass into shales; thereafter nothing can be seen for the recent alluvium of Mindon *chaung*. To the south-east, Shwenat-taung pagoda (19° 16′; 94° 53′) stands on the summit of a 400 feet high cliff which runs east north-east, and is made up of massive irregularly bedded fine sandstones dipping south-east at 25°. This latter series is apparently the same as the one forming the steep slopes of Theobyit *Taung* (19° 16′; 94° 55′) to the east, the high cliff being a fault scarp.

North-west of the south and old village of Thakutkyaw, blue shales with occasional thinly bedded sandy and limy bands and ferruginous concretions dip north-east at 60° in the stream bed. Some contortion of the shales and a fair amount of vein calcite debris are also present north-west of the Thakutkyaw-Pazinda

(19° 20′; 94° 55′) track crossing. Eastwards the stream meanders through shales followed by shales with sandy reinforcements dipping northeast at 75°, and these latter, where the valley closes in, by a bedded sandstone series with occasional shale bands. The sandstones are soft, fine-grained and efflorescent, whilst harder and ferruginous lenticles are intermittently interspersed in the shales. *Discocyclinae* were found in some of the blocks but were not seen *in situ*. Blocks of the concretionary type of Eocene foraminiferal limestone and a little gypsum were noted in the stream bed. Soft blue shales then give place, eastwards, to the second band of limestone, which cuts the *chaung* one mile east of Thakutkyaw. The limestone is from 8-10 feet thick and is made up of concretions and various species of *Discocyclinae.* Soft shaly sandstones with harder lenticles follow and then, just east of the stream junction, thick blue shales with harder sandy bands dip N. E. by E. at 55°. These shales weather spheroidally and the stream meanders through them to the next stream junction one and a half miles east by south of Thakutkyaw. Westwards from this junction up the southerly tributary a similar sequence of shales with sandy lenticles, soft efflorescent sandstones, shales with sandy reinforcements and isolated small ferruginous concretions, and shales is met. The dips vary from 75° N. E. by E. in the vicinity of the limestone band to 40° N. E. in the shales with reinforcing sandstones, steepening again to 70° N. E. 5° E. further west.

This stream is the one I identify as that examined by Theobald[1] in detail and the one for which he gives the following section in descending order :—

	Ft.	In.
MIOCENE.		
Greenish gray, earthy sandstone, shaly in places, but mostly massive, over	100	0
UPPER EOCENE.		
Nummulitic limestone	10	0
Soft sandy and shaly beds (ill seen)	65	0
Hard yellowish argillaceous sandstone	1	0
Soft beds (ill seen)	80	0
Fine greenish gray silty sandstone, micaceous, rather slabby, with some shaly partings	6	6
Pale shales	1	6
Dark shales and soft beds (ill seen)	75	0

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[1] *Mem. Geol. Surv. Ind.*, Vol. X, pp. 286 and 287, (1873).

UPPER EOCENE—*contd.*

	Ft.	In.
Hard grey sandstone with marly lumps	2	0
Soft shales	30	0
Sandstone, silty in parts and irregularly bedded	1	0
Soft shales	70	0
Hard marly band	0	9
Soft shales	50	0
Silty sandstone	2	0
Dark shales	20	0
Hard sandstone	1	0
Dark shales resting on hard sandstone	26	0
Soft beds (ill seen)	90	0
Fine massive greenish sandstone	10	0
Soft beds	25	0
Massive earthy sandstone	5	0
Pale clunchy shale	4	0
Nummulitic shale	0	9
Pale clunchy shale	11	0
Nummulitic shale	0	9
Dark shale, flaky below	4	0
Flaky sandstone	1	6
Pale shales, somewhat silty	2	0
Shales dark and clunchy	11	0
Pale earthy sandstone, shaly at base	1	6
Hard sandstone	0	9
Soft shales with a little sandstone	35	0
Flaggy sandstone	3	0
Flaggy shales	20	0
Hard sandstone	1	0
Greenish sandstone with soda efflorescence	80	0
Greenish shales with soda efflorescence	50	0
Massive sandstone	3	0
Shales pale and silty	20	0
Massive sandstone, with a few beds of shale	175	0
Pale shaly beds	90	0
Thin bedded silty sandstone	1	0
Arenaceous shales, with carbonaceous markings	50	0
Pale arenaceous shales with rusty laminar concretions and carbonaceous markings	5	0
Dark brown shale, clunchy at base	80	0
Compact bluish sandstone with some carbonaceous matter	1	0
TOTAL	1,223	0

Theobald remarks that the section though not everywhere well exposed and lying on a small and somewhat tortuous stream gives nevertheless a good idea of the beds of the Upper Eocene group and generalises it as follows :—

MIOCENE.		
Clay and sandstones	..	
UPPER EOCENE.		
1. Nummulitic limestone	10	0
2. Shales and sandstones ; shales occasionally nummulitic .	658	0
3. Massive sandstones with some shales and much soda efflorescence in places	328	0
4. Shales and sandstones, the shales with some carbonaceous markings	227	0
TOTAL .	1,223	0

Continuing Theobald[1] remarks—

> 'The limestone at the head of this section is, as far as can be judged, the highest bed of the Nummulitic group : and its variable thickness, for in many places it must be from sixty to a hundred feet thick, is quite in accordance with that general irregularity of development which, as I have already described, causes it in places to thin out abruptly and disappear. There can, however, be little doubt that this topmost bed of the group is the same bed which can be traced at intervals from near Phoungyi to the Pyengma stream in the Bassein district, a distance in a direct line of two hundred and twenty-four miles. That it is not more largely met with than it is, seems partly attributable in its irregular development, and partly no doubt to the extensive denudation it has undergone during the most recent times and subsequent to the formation and arrangement of the general surface features of the ground at present '.

Three quarters of a mile north-east of Thakutkyaw, concretionary limestones with foraminifera form a dip slope, over which the Pazinda track passes, and more of the same type of limestone forms the ridge on the high left bank of the *chaung* to the east. Further to the east, the rocks consist of soft fine sandstones grading into shales, whilst a hard fine limy band forms the subsidiary N. W.—S. E. watershed one and a half miles south-west of Pazinda village.

South by east of Thakutkyaw are almost vertical shales, and, where the Pyinaing (19° 17′ ; 94° 56′) track crosses the stream one mile south-east of Thakutkyaw, similar shales dip north-east at from 60° to 70°. Vein calcite is found in this series. Along the Pyinaing track to the east thin bands of foraminiferal limestone occur, giving place after half a mile, to a band of grits, occasionally ferruginous, which form a ridge, and are succeeded by a glauconitic grit one and a half miles S. E. by E. of Thakutkyaw. The ridge a little further to the east appears to be formed of a limy band in shales, as, although limy nodules are common in the soil cap, no other rocks are to be found.

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[1] *Ibid* p. 288.

Mindon road.

West of Mile 33·1 on the Mindon road the sandstone series with Eocene foraminifera is succeeded to the west to the Tishe *chaung*-Aingma *chaung* junction at Mile 34-1, by a series of massive sandstones with shaly sandstone intercalations, dipping north-east. From here to Mile 36 a massive sandstone series prevails. This series is bluish in colour and contains broken leaf impressions, but otherwise appears to be completely unfossiliferous. The Aingma *chaung* cuts through it in a rocky bed, whilst the slopes both north and south are steep and thickly covered by forest and undergrowth. The road follows the *chaung*, at one place running along the bed for some hundred yards. After heavy rains, as at the time of my visit, the water was about three feet deep and flowed torrentially.

West of Mile 36, the series becomes more shaly and reefs of Eocene *Discocyclinae* and nummulites appear. This shaly sandstone and shale series forms the ridge west of Mile 37 and continues southwards to Kanle (19° 20′; 94° 47′) being covered locally by river gravels of vein quartz and quartzite up to 10″ in diameter.

Saingdo: (19° 23′; 94° 48′).

North of the Mindon road, the Aingma *chaung* at Saingdo (19° 23′; 94° 48′) flows in blue shaly sandstones with harder more calcareous lenticles, which are very like the Pegu sandstones occurring along the Mindon *chaung* in Sheet 85 1/16 to the south. The occurrence of Eocene foraminifera on the gravel banks, and further work to the south, proved definitely, however, that they are of Eocene age.

East of Kanle, paddy fields obscure the solid geology to Mogaung (19° 20′; 94° 48′) village. From the latter place to the east, shaly sandstones with Eocene foraminifera dip east at 40° and form the lower slopes of the ridge. In the sandy bands in the series, occasionally small knots of foraminifera sometimes only two feet in length are seen. This shaly sandstone series is very similar to the one forming the ridge north of Kanle; it contains the same fauna and possibly is a part of the same series. Otherwise, a small strike fault may occur along the valley of the Aingma *chaung* to the west.

From where the steep ascent to the ridge east of Mogaung commences, no foraminifera were seen in the harder sandstone series overlying the foregoing. These latter rocks dip E. 15° N. at 35° and contain laminated (½″) bands and more massive bands (6 to 8 feet) and lenticles. Northwards from the summit of the ridge, along the watershed, big sandstone lenticles dip east, and E. 15° S. at from 10°—20° until the solid geology becomes obscured by soil cap. Where the watershed runs west, sandstones appear to dip south at low angles but the exposure is precipitous. Further west on the Thambula reserved forest boundary sandstones dip W. 25° S. at 35 , further west still, debris obscures the change of dip to north-east, west of Thayetsan.

Kyingyi (19° 19′; 94° 48′).

South-west along the Kyingyi path on the Thambula reserved forest boundary, only sandstones of the type seen on the Aingma *chaung* to the north-west are seen; they dip south-west but the dip gradually changes to south towards the stream immediately north of Kyingyi. At the latter place the dip which has averaged about 40° decreases to 25 in sandy shales with harder lenticles. No Eocene foraminifera were found in the gravel banks of the stream.

On the Gyogon (19° 18′; 94° 48′) track in the stream immediately south of Kyingyi flagstones intercalated in a sandy shale series dip E. 5° N. at 40° so that Kyingyi lies along the axis of a syncline. The flagstone series continues to Gyogon, the direction of dip changing gradually to E. 25° S. at 35° half a mile north-east of the village, but steepening to 50° as the village is reached.

South of Kanle.

Due south of Myenigon (19° 19′; 94° 47′) on the right bank of the Mindon *chaung*, soft sandy shales surmounted by gravels dip north by east at 60° and then east by north at 20° a little further south. Sandy rocks with harder ‘doggers’ are seen along the road to the Thanyan (19° 18′; 94° 47′) village cart track junction, at one place dipping S. 30° E. at 85°. At the latter place sandstones dip W. 25° S. at 40° giving place eastwards towards Thanyan to laminated soft shaly sandstones dipping north-east at 30° and N. 25° W. at 25°. Immediately west of Thanyan, vertical grey grits strike E. 20° N. whilst within the precincts of the village a soft laminated shaly series dips 70° E. 10° S. Faulting has evidently taken place in this area; it cannot however be made out specifically in this featureless jungle country.

Mu *chaung*: south of Thanyan.

From Thanyan down the Mindon *chaung* weathered sandstones, mottled green and brown, appear in the angle of the stream three furlongs south-east of Padon (19° 18′; 94° 47′), whilst bedded fairly massive sandstones dip E. 15° S. at 35° on the left bank immediately below Mibauk (19° 18′; 94° 48′). Five furlongs east of Sagade-anauk (19° 17′; 94° 49′) sandstones dip 30° E. 15° N. and laminated sandstones with harder bands dip E. 20° N. at 30° one mile N. W. by W. of Kyaukse (19° 18′; 94° 50′). South-west of Kyaukse the massive sandstones forming the high left bank of the river appear almost horizontal.

Kinbongaing: (19° 17′; 94° 50′).

West from Kinbongaing (19° 17′; 94° 50′) on the right bank of the river on the southerly track to Gwedaukcho (19° 14′; 94° 50′), practically horizontal shaly blue sandstones with harder calcareous bands (6″), sometimes ferruginous, reinforcing them, are first seen. Where the dip can be made out it is south by west at 10°, changing to the south by west, to 15° north-east. Underlying the latter are soft rather shaly sandstones with ferruginous and calcareous bands dipping north-east at 40°. In these at one place minor jointing was so regular as to give the appearance of setts. Laminated sandstones with intercalated doggers and shales dipping E. 25° N. then continue to the south-west to 20 yards east of the Htaukyit (19° 17′; 94° 48′)—Gwedaukcho cart track, where an Eocene foraminiferal reef, containing species of *Discocyclina,* occurs in soft sandy and shaly rather laminated strata. This reef was reported to occur intermittently northwards to Sagade-anauk and south to Gwedaukcho. West of the reef the rocks become more shaly and support a little cultivation; they contain thin ferruginous bands and stringers and nodules of calcite. One hundred and fifty yards north of the foraminiferal reef above-mentioned, on the Sagade road, other foraminiferal reefs were noted on the line of strike of the first one. Occasional quartz gravels on the ridges point to this country having been covered by gravels within recent times.

East of Kinbongaing along the Thambula track, soft and occasionally laminated sandstones dip S. 30° W. at 30° and are underlain by soft weathered fawn sandstones which dip south-west at 35°. In the more shaly strata below the latter on the 300-foot contour, an Eocene foraminiferal limestone, three yards thick, dips S. W. by S. at 20°. Below the reef, soft sandstones, with harder limy and slightly ferruginous bands, dip in the same direction at 25°, and in these a tough ferruginous fossil conglomerate with ironstone nodules contains broken lamellibranchs and gastropods. One of the big gastropods appears to be *Ampullina grossa*, Desh. Similar rocks continue to the east, the dip, where the steep ascent commences to the forest boundary gradually steepening to 35°. Rather laminated shaly strata with ferruginous bands, much more shaly than to the immediate west, continue to the stream to the south-east, where shaly strata dip N. E. by E. at 80°. A crushed zone follows in which the dips vary from S. W. by S. at 80° to N. E. by E. at 80° and is succeeded by a sandy series dipping S. W. by S. first at 60° and then on the watershed at 40°. Soil cap and debris obscure the solid geology on the Thambula side of the watershed.

Down the Mindon *chaung* below Kinbongaing practically horizontal massive sandstones continue to a third of a mile due south of Tanlebin (19° 16′; 94° 52′), where a reef of *Discocyclina* and nummulites caps a mass of bluish soft sandstone and dips N. E. by E. at 15°. On the left bank above the Hlwawa stream junction, bedded shaly sandstones dip east by south at from 15°—20°; the same series are also seen on the right bank on the north-east reach of the river below the junction. The photograph (Plate 12, Fig. 1) was taken from the right bank of the Mu *chaung* half-a-mile S. W by W. of Leye (19° 16′; 94° 53′) and looks N. E. by E. at Shwenattaw pagoda. The Shwenattaw pagoda stands on a scarp of sandstones (post-Eocene) precipitous to the north-west; the summit on which the pagoda stands is nearly 1,000 feet above the level of the river below, and consists of massive soft sandstones dipping S. E. at 25°. The cliff north of the pagoda is about 400 feet high and made up of massive soft irregularly bedded fine-grained sandstones. Below the massive sandstones, on the slope west by south of the pagoda, a few specimens of *Lepidocyclina* (Oligocene) were collected in fine sandstones; tufa occurs in the stream west of the pagoda.

Half mile west by south of Leye (19° 16′; 94° 53′), greenish blue sandstones dip E. 20° S. at 30° and continue to the south-west

Leye: 19° 16'; 94° 53').

along the Kabaing (19° 13'; 94° 50') track. All the valleys in this area are steeply cut and gravels cap the ridge at about the 250 feet contour south-west of Leye. Sandy strata with harder lenticles continue to the south-west to S. E. by E. of Hlwawa (19° 15'; 94° 52') and gravels with boulders of Axial detritus up to one foot in diameter occur intermittently on the ridges up to a height of 370 feet. Half a mile due south of Hlwawa, where a reef of argillaceous Eocene foraminifera occurs in soft greenish sandstones with harder marly bands, the dip changes to E. 10°, N. at 30°; the series continues with the same dip along the ridge to the track junction just over a mile to the south. West by south from this junction, is a sandy series weathering out as lenticles and crowded with tests of the gastropod, *Turritella*; it continues in the high ridge to the south-west, whilst along the track, which hereabouts runs due west, no exposures are visible, but from the soil-cap the rocks appear to be much more clayey than in the ridge. On this track one-and-a-quarter miles N. E. by E. of Kabaing a band of foraminiferal limestone containing various species of *Discocyclina* was found dipping east by south at 40°. The limestone is of the concretionary type, and in addition to foraminifera contains broken lamellibranchs.

Monda.

Seven miles to the south in the stream about 600 yards west by north of Monda (19° 8'; 94° 54'), fine bluish-green sandstone dips E. 5° S. at 30°. Further up the stream they are succeeded by more shaly types containing, at the top, a weathered shaly band of foraminifera dipping E. 10° N. at 35°. The band is 12 feet thick and contains species of *Discocyclinæ* and echinoid tubercles. In this more shaly series are harder dogger bands but the shale bands are fairly homogeneous and weather spheroidally. West of the compact foraminiferal limestone band containing *Discocyclinæ*, nummulites and corals, one and a quarter miles west of Monda, shales dip E. 10° N. at 30°, but the series becomes sandy where the Monda-Sayan (19° 9'; 94° 52') track leaves the stream bed, and here on the north bank is a band of foraminiferal limestone from 6-10 feet thick. This band continues north over the watershed to immediately west of the western tributary of Pyagyi *chaung*. From this band *Lithothamnium* was also identified. East of the limestone band at the latter locality, calcareous tufa is deposited in the *chaung* bed. Westwards over the watershed on the Sayan track fine-grained bluish sandstones, dipping E. 10° N. at 60° (approx.), form a scarp, whilst the same dip prevails in fine-grained, bluish, bedded sandstones one third of a mile east of Sayan. North from the latter locality, blue shales with thin intercalated fine limy sandstones dip E. 15° N. at 50° in the head-waters of Mibauk *chaung*. Shaly strata dipping in the same direction continue north down Mibauk *chaung* and in a limy sandstone two and a half miles south by east of Mibauk, specimens of *Conus*, *Natica*, and *Cardium* were collected. One and a quarter miles south of Mibauk (19° 12′; 94° 52′) a foraminiferal limestone band very similar to the one seen three quarters of a mile west of Monda was encountered, whilst north of this band, where the stream passes through the thick blue shales of the Mibauk valley, vein calcite is common.

In the southern branch of Monda *chaung* where the valley closes in one mile south-west by south of Monda, a 20-foot band of limestone strikes across the *chaung* and dips 40° south-east. The band contains large *Discocyclinæ* of from 3″-4″ diameter with crenulated margins, *Discocyclina omphalus* and a variety of other species as well as the large nummulite mentioned from east of Thayetsan. Below this limestone occur sandy strata dipping at the same angle, and immediately after the bend in the stream one and a quarter miles S. W. by S. of Monda, shales with sandy and limy lenticles and calcareous concretions. The latter dip E. 15° N. at 15°; the change of dip is sudden and faulting has evidently occurred. Sandy strata with a thick soil cap form the watershed to the west.

West of Kyein Taung on the Gyinye (19° 6′; 94° 54′) track, three quarters of a mile south of Monda *pongyi chaung*, beds of fine-grained blue micaceous sandstones from one to two feet thick with softer six-inch intercalations dip south-east at 35°. Overlying them is a 12-foot band of *Discocyclina* shales which grades into the sandy series. On the Gyinye side of the watershed further south, *Discocyclina* limestone dips south-east at 55° across the path. These limestones contain a fauna similar to the bands west and south-west of Monda.

Gyinye.

The Gyinye valley is obscured by rice fields, but to the west by north up the main feeder to Gyinye *chaung*, there is a band of fine-grained blue micaceous sandstones down the dip slope of which the stream descends for 100 feet. At the bottom of the slope is a huge cauldron 6 feet deep and 12 feet in diameter, whilst a similar cauldron occurs at the top. Further west, bands of *Discocyclina* limestone, similar to those just mentioned, dip due east across the stream and are associated with fine-grained to shaly blue sandstones. Above the bend one mile west by north of Gyinye, bands of the same limestone dip E. 25° N. at 40° in shaly blue sandstones which weather spheroidally. From here the stream-bed follows the strike of the rocks until near its source, where an alternating series of fine-grained micaceous sandstones and shales dips E. 25° S. at 35°. Further to the north-west the soil-cap is thick and exposures non-existent.

Yebokkale *chaung* (19° 5′; 94° 55′).

Half a mile south-west of the jungle village of Yebokkale *chaung* (19° 5′; 94° 55′) on the ridge crossed by the Gyobin road, sandstones dip S. S. W. at 30°. They are followed first by foraminiferal (*Discocyclina*) sandstone dipping in the same direction at 40° and then by a hard tough foraminiferal limestone containing *Discocyclinæ* and nummulites. The latter dips E. 70° S. at from 60°- 70°. Faulting appears to have taken place and vein calcite is very common to the north of this limestone exposure, where, along the watershed, coarse foraminiferal sandstones very like the uppermost band in Gyinye *chaung* two miles N. W. by N., and a great deal of calcite and brecciated sandstone rock occur.

North-west of the peak one mile south of Yebokkale, *Discocyclina* sandstones and limestones dip south by east at 40°. Here the series of foraminiferal rocks is thick and very like the Gyinye series; it appears to be the southerly pitching end of a small faulted anticline.

On the track, one and a half miles N. E. by N. of Gyobin (19° 2′; 94° 54′), the strata dip S. S. W. at 60° whilst a quarter of a mile nearer to Gyobin slightly ferruginous limestone containing nummulites and *Lithothamnium* dips N. E. by N. at 30°. The latter is followed to the south by fine-grained rather limy, micaceous sandstones with traces of fossils. Just north of Banbyin village (19° 2′; 94° 55′) quartz pebbles crown the ridge, whilst the alluvium of Made *chaung* conceals the solid geology of the Gyobin valley.

One and a quarter miles N. E. by E. of Gyobin, where the steep ascent on the Thapangyo (19° 5′; 94° 57′) path begins, argillaceous limestone bands containing *Discocyclinæ* dip E. N. E. at 40°. On the watershed above, fairly fine-grained sandstones dip first E. N. E. at 50° and then E. 20° S. at 50°. Half a mile north of Kadan *Taung* (19° 3′; 94° 56′), sandstones dip north-east at 20° but this dip may be of a local nature. In the *chaung* which rises immediately north-west of Kadan *Taung*, paddy fields occupy the upper part of the northern reach. They are followed down-stream first by fine-grained sandstones dipping E. N. E. at 55° and then by thinly bedded sandstones and shales, a waterfall being formed where false-bedded blue sandstones 50 feet thick dip E. 30° N. up the *chaung*. This latter band is followed by thinly-bedded blue sandstones in which a *Discocyclina* band dips north-east at 60°. Down stream disturbed strata occurs to the paddy fields.

Peinnekwin: (19° 3′; 94° 58′).

Immediately west of the village of Peinnekwin (19° 3′; 94° 58′), shaly strata are followed by argillaceous *Discocyclina* limestone bands dipping N. E. by E. at 45°. These bands are followed to the north-west by very broken and brecciated strata and then by soft blue shaly sandstones dipping south-east at 30°. The latter continue to the junction one mile N. W. by W. of Peinnekwin. Above the junction, soft blue, micaceous, and rather shaly sandstones dip E. 30° N. at 60°; they continue, forming small waterfalls where the harder bands cross, to two miles N. W. by W. of Peinnekwin. There, a band containing the large nummulite previously mentioned crosses. South-west from here on the watershed at a height of 550 feet, coarse foraminiferal sandstone dips E. 30° N. at 60°. Just west of the summit of Kadan *Taung* a band of foraminiferal sandstone dips E. 30° N. at 50°; the dip in the same band steepens to the south to 60° in fawnish rather 'tuffy' looking sandstones.

On the ridge half a mile N. W. by W. of Pingadaing (19° 2′; 94° 59′) a compact glauconitic fossiliferous limestone, containing *Discocyclinæ* and small nummulites, dips east at 44°. It disappears to the south and no trace of it could be found in Kyaukme *chaung* which cuts the ridge on the south.

CHAPTER IX.—DETAILED DESCRIPTION OF ROCKS. 'THE PEGU SYSTEM'.

Physical characteristics of rocks.

The Pegu system consists of an alternating sequence of sandstones and clays in which calcareous bands sometimes play an important part. They have been described fully by Pascoe[1] who in his account states (p. 17).

> ' One of the most striking characteristics is the impurity of the various sediments and the rapid and capricious alternation of clays, sandstones and calcareous bands There is every gradation between a sandstone and a clay and it is rarely that one unmixed with the other is found...... The proportion of one constituent may increase laterally and a sandy clay pass into an argillaceous sandstone. A less intimate form of mixture produces one of the commonest types of all, a series of alternating laminæ of layers each from an inch to a foot or more in thickness, of impure sand and clay: either kind of layer may decrease laterally and the composite bed pass into a sand or a clay as the case may be. Current-bedding is not so frequently met with as it is in the overlying Irrawadi Sandstone, but it is by no means uncommon. As a rule the lenticular habit of the beds is on a larger scale and not apparent in small sections. Small local unconformities and examples of contemporaneous erosion exist here and there at no particular horizon. ....The hard calcareous and often fossiliferous bands consist of sand mud and oxide of iron, cemented by calcareous matter: as the latter is always of secondary origin and the bands inconstant, they must either die out or pass laterally into a sand or a clay. Sometimes the proportion of sand is very small and we get a hard ringing limestone. In fact there is again every gradation between this and a crumbly shell marl....... Not only in flat bands, but also in spheroidal or irregularly rounded concretionary masses with planes of stratification passing across them, does calcareous sandstone occur and there is every gradation from spheroids, through more and more flattened spheroids to flat slabs or bands. The latter are often only six inches to one foot in thickness; they are known as shells by the drillers........ Some of these hard slabs show beautiful ripple-marking which had been formed in the soft sand before the infiltration and deposition of carbonate of lime.'

Included in the Pegu system are all rocks between the upper boundary of the Eocene and the lower boundary of the Irrawaddy series.

In the north of the area under description the system has been divided up as follows:—

Sub-division of Pegu system in north Minbu.

Pegus (restricted)—
- Upper shallow water series with selenite.
- Upper shaly group.
- Middle marine limy group with intercalated shales.
- Padaung Clays.
- Shwezetaw Sandstones.

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[1] *Mem. Geol. Surv. Ind.*, XL, Pt. 1, p. 14, *et seq.* (1912).

In the south at the latitude of Kama (19° 1′; 95° 9′) the following divisions can be recognised—

1. Alternating sandstones and shales.
2. Massive sandstones (Prome Sandstones of Theobald).
3. Shales.
4. Sandstones, seen at Kyaukme (19° 1′; 94° 59′) on Made *Chaung*.
5. Shales.

Kyaukme sandstones, Okhmintaung ridge sandstones and Monatkon sandstones the same.

In the Thayetmyo district, continuous mapping northwards from the latitude of Kama along the western outcrops, has shown that the horizon of sandstones in the Pegu system, exposed at Kyaukme, forms the Okmintaung ridge north of the Thayetmyo (19° 20′; 95° 14′)—Mindon (19° 21′; 94° 50′) road. Eastwards, on the other side of a syncline, the same sandstones form the flanks of the Monatkon (19° 32′; 95° 3′) and Okpon (19° 28′; 95° 3′) domes. These sandstones are overlain by a series of shales in the Magyigon (19° 29′; 94° 57′) and Kadetpin (19° 29′; 95° 2′) valleys and are overlain by sandstones below the Irrawaddy-Pegu junction north-west of Thayetmyo. On the river south of Thayetmyo, the same sequence of sandstones, shales, sandstones, in descending order, is met with below the Irrawaddy boundary. A sketch map of the Irrawaddy river south of Thayetmyo showing details of rocks of the Pegu system is given by Stamp[1]. It will be seen that the upper part of this section corresponds to the upper part of the section at Kama.

The unconformity and overlap of the Irrawaddy sandstone on the Pegu system, is very difficult to make out in the north, in areas where the outcrops of the beds run parallel with the main range. Where the dips are fairly high the boundary is obscured by pebble debris from the Irrawaddian basal conglomerates. It becomes a little more obvious to the south, where folding and denudation has exposed the boundary over a more extensive and gently folded E.-W. section, or even at a series of places in a N.-S. line. There the Irrawaddy sandstones are sometimes found overlying Pegu sandstones and at others alternates and shales of the uppermost rocks of the same system.

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[1] *Geol. Mag.* LXII, p. 523, (1925).

The development of the Okhmintaung ridge sandstones has, in the past, been the chief difficulty in correlating the Pegu system along the Irrawaddy valley from Kama northwards. The base of the post-Eocene rocks are not exposed in the Lime Hill, the only rocks showing being the equivalent of the Padaung clays, in which there is a development of *Lepidocyclinæ*. Similar *Lepidocyclinæ* occur due west of this, in the western outcrops below the sandstones of the Shwenattaung Pagoda ridge and west by south of Lebya, on the Mindon *chaung*.

At latitude 20° 30′, the lower divisions mapped further north are still prominent, and it was possible to map Shwezettaw sandstones and Padaung clays southwards throughout Sheets 84 L-7 and 84 L-8.

Shwezettaw sandstones. Sheet 84 L-7.

West of Myaung—U (20° 30′ ; 94° 21′) the upper horizons of the Shwezettaw sandstones consist of sandstones with intercalated shelly conglomerates. Lower in the sequence the sandstones become much more calcareous although true sandstones and conglomerates do occur. Fossils are found as a rule in the more limy bands but only fragmentary specimens can generally be collected from them. The series dips at an angle of about 30° and is underlain conformably to the west by the Yaw shales.

A similar sequence is seen west of Aleban (20° 27′ ; 94° 21′) four miles to the south, and in the Mon *chaung* section a further six miles to the south, subsidiary scarps are formed in the series where thick calcareous bands occur. The latter give rise to small falls in the streams, which, in the rains, flow down dip slopes to the Thabye *chaung* to the east. The whole series attains a thickness of about 3,000 feet in this area.

Padaung clays. Sheet 84 L-7.

To the east overlying the Shwezettaw sandstones are the Padaung clays. Part of the village of Myaung-U occurs on the lowest horizons of them, but the main sequence is found further east where it consists of two bands, a lower and an upper. The lower band has a thickness of about 800 feet and the upper of 700 feet and they are separated by a series about 330 feet of ‘pepper and salt’, gritty and sometimes reddish sands with fossiliferous bands. The upper band passes northwards into a typical Pegu alternating series of sandstones and shales, whilst the lower band continues northwards to form the well defined shale band of the Ngahlaingdwin anticline.

At Myaung-U the shale bands are apparently unfossiliferous, but to the north the lower band at Ngahlaingdwin (20° 41′ ; 94° 23′), contains foraminiferal limestones of Oligocene age. To the south the upper clay horizon thickens considerably, whilst the sandy zone separating the two bands thins and develops shale bands between the gritty sandstones. The whole series dips due east at about 30°, changing at the Mon *chaung* crossing to E. 30° N. at about the same angle. The main shale horizons accommodate long meandering subsequent streams, and, of these, the Thabye (20° 22′ ; 94° 21′) and Aleban enter the Mon *chaung* from the north and the Chaungzauk (20° 23′ ; 94° 18′) and Dahat (20° 22′ ; 94° 18′) from the south.

Pegu Series (restricted) northern part of Sheet 84 L-7.

The restricted Pegu series in this area, though as a whole an alternating series of marine and estuarine facies, at various horizons does contain a predominance of types and can be divided into an upper sandy, a middle shaly and a lower limy and sandy series.

Middle limy and sandy series.

The base of the lower limy and sandy series forms the scarp east of the Aleban valley in the north, and the Chaungzauk valley in the south. It consists from the base upwards of alternating sandstones with thin limy bands, followed by shaly sandstones and ripple-marked pepper and salt sandstones. This facies prevails to a band of hard massive sandstone, 25 feet thick, 1,500 feet from the base, which cuts across the *nalas* and forms a marked feature, being responsible for the minor much dissected scarp on the 1′=1 mile topographical sheet. Eastwards from this band, shales begin to appear as noticeable horizons, and a gradual transition into the middle shaly series takes place. Occasional contemporaneous conglomerates with soft shale pebbles, and horizons containing broken fossils are present throughout the series, which has a total thickness of about 3,300 feet.

Upper shaly series.

The middle shaly series is if found along the bed of the Shasibo *nala* ; it has a thickness of only about 1,000 feet in this area, but forms a marked division between the hard shelly grits below, and the fawn coloured sandy strata above. On the east, in the middle of the sheet, the scarp carrying the Nyaunggon (20° 20′ ; 94° 23′)—Maung-U road forms its upper boundary, but to the north towards the Salin (20° 35′ ; 94° 40′)—Sidoktaya (20° 27′ ; 94° 15′) road, it loses its identity owing to the number of thin sandstone bands which are spliced in from the north.

Upper sandy series.

The upper sandy series is characterised by soft fawn coloured sandstone, varied by thin, harder, and more ferruginous bands, and occasional shaly pebbly and gritty conglomerates, the shale pebbles of which are extremely ferruginous in character, and probably derived from underlying horizons of the same series. The fawn coloured sandstones, ferruginous mud conglomerates, and harder gritty bands, are of a shelly nature in the lower horizons; in the upper, shelly horizons are absent, but two horizons in which selenite is abundant occur. This upper series of the Pegu system is nearly 6,000 feet thick.

Pegu sequence in south of Sheet 84 L-7.

In the lower band of the Padaung clays in Dahat *chaung* in the south of the sheet, Sethu Ram Rau reports in his progress report for 1912-13 the collection of the following fauna :—

Calcellaria martiniana
Turritella Lyddekeri
Solarium and *corals*
Dentalium.

Eastwards the Pegu beds consist, according to the same authority, of sandstones and limestones of which some are fossiliferous. Exposures are rare, even in the stream beds, and the only other fossiliferous zone which could be marked with certainty, is that occurring two miles west of Chaungzon (20° 17′; 94° 28′) village, where the following were collected :—

Batissa Crawfurdi.
Batissa Kodaungensis
Telescopium subtrochleare.
Arca rhombea.

Overlying this zone the Upper Pegu series consists of sandstones conglomerates and very subordinate shales. Selenite is present in many localities and characterises the series.

To the south-east on the same strike as the upper shale band of the Padaung clays, half a mile south-west of the deserted village of Kyauk-o (20° 10′; 94° 31′) in Sheet 112, Cotter found limestone containing *Heterostegina sp.*, *Pecten sp.* cf. *subarcuatus*, Tourn, and minute nummulites. This limestone is associated with shales, and continues to the south-east to form the upper horizon of the Padaung clays in the Man *chaung* section. From the upper division in Sheet 84 L-7 near Chaungzon village (20° 17′ ; 94° 28′) Cotter collected *Cyrena Khodaungensis* and *Ceritheum sp.*

Shwezttaws and Padaungs of Man *chaung* section.

In the Man *chaung* section, the Shwezettaw sandstones consist of sandstones with intercalated grits, flagstones and limestones. Occasional bands are shelly and brittle, and one thick shale band occurs in the series. The renowned pagoda of Shwezettaw, which stands on the ridge south of Payaywa (20° 7′ ; 94° 35′) village, consists of conglomerates and flagstones, the latter of which are extensively used for steps to the upper pagodas.

North of Payaywa—the village lies in a shale valley—is a conglomerate band, which corresponds to the shelly grit separating the lower from the upper clay bands of the Padaung clays on the Man *chaung* to the north. Half a mile N. W. by N. of Payaywa village, it is overlain by shales containing a limestone, from which *species of*, *Schizaster Heterostegina* and *Pecten* were collected. The grit is seen again south of Thanbayagaing (20° 5′ ; 94° 37′) and is overlain on the peninsula on which Thanbayagaing stands, by a thick series of blue clays with intercalated foraminiferal limestones.

Repetition of part of Padaung clays on west of main range.

A repetition of these foraminiferal limestones occurs in the syncline south of the site of Sabagyidan (20° 4′ ; 94° 34′) (no village now exists), on the west side of the main range, where the following collection was made.

Lepidocyclina elephantina, Munier-Chalmas=Orbitolitis Mantelli Cart. var. theobaldi Cart.
Lepidocyclina sp.
Heterostegina sp.
Schizaster sp.

A small well-marked fault cuts west-north-west from the main strike fault across this limestone syncline, and is visible on the north bank of the Man *chaung* immediately north of the village of Thakutpin (20° 4′ ; 94° 33′).

To the south-east in Sheets, 84 L/8 and 84 L/12, a shale band, which thickens to the south, divides up the Shwezettaw sandstone into two main sandstone, scarp-forming bands. The series as such is continuous throughout the sheets.

The upper band of the Padaung clays thickens considerably, and foraminiferal limestones containing Oligocene species develop in it along the Man *chaung* north-west of Padaung (20° 3′; 94° 39′). This area is the type locality of the Padaung clays, and whereas it is the upper band in this area which provides the Oligocene fauna, it is the lower band at Ngahlaingdwin (20° 41′; 94° 23′) 40 miles to the north in which a similar fauna is found.

Throughout the Pegu series, shales have become increasingly dominant in this Man *chaung* section.

The whole of the section has been described by Dr. Cotter[1] who states (p. 222):—

Cotter: Descriptions of Man *chaung* Section.

[1] The Pegu series are marine and estuarine deposits, containing the usual assemblage of fossils which are in the middle of the series most frequently characteristic of the *laminaria* zone.

It is not proposed in this paper to describe the fauna of the Pegu beds, except those of their basal division, the "Siteayan Shales" but it is worth noting that as one traces the series northwards, there are evidences of shallower and shallower water; thus fossil wood is rare but present in the north of the Minbu district near Ngahlaingdwin (Lat. 20° 41′; Long. 94° 22½′) while in the Pakokku (21° 20′; 95° 8′) district it is abundant in the Pegu series, and the sandstones at times simulate the current bedded Irrawaddy series.

Towards the base of the Pegu series there is an easily recognisable zone of clays, blue grey in colour, containing a subordinate bed of grey earthy limestone-marked "C" on the map—which apparently dies out south of Padaung village. Northwards we have not followed it up beyond Pavavwa village. The zone of clays is perhaps 1,300-1,500 feet thick, the limestone bed being in the upper part, and of a thickness of 35 feet near Thanbayagaing village (locality C.3). About 70 feet above the limestone at this locality the following fossils were found in the shale:—

Cancellaria martiniana Noetl.
Conus protofurvus Noetl.
Turritella angulata Sow.
Solarium sp.
Cytherea sp.

The limestone bed contains the following both in this and other exposures:—

Lepidocyclina elephantina Munier-Chalmas. (=*Orbitolites Mantelli* Cart. var. *theobaldi* Cart.)
Heterostegina sp.
Pecten (*s. str.*) *sp. cf. subarcuatus* Tourn.

In the shales below the limestone at "C.3" the following species were found:—

Fasciolaria nodulosa Sow.
Conus literatus Linné.

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[1] *Rec. Geol. Surv. Ind.*, Vol. XLI, p. 221, (1912).

Cancellaria martiniana Nœtl.
Tellina sp. cf. protocandida Nœtl.
Tellina sp. cf. hilli Nœtl.
Turritella angulata Sow.
Strioterebrum sp.
Pleurotoma cf. karenaica Nœtl.
Ficula sp.
Genota sp. cf. irravadica Nœtl.
Dione sp.
Crab claws.

and below the limestone at "C.2" a species of *Schizaster* resembling *S. baluchistanensis* D'Arch. These fossils are characteristic of a Nari age, and most probably upper Nari, corresponding with the Lower Aquitanian of Europe.

"I obtained from a villager of Thanbayagaing some specimens of *Lucina globulosa*, Desh. which he brought at my request from a locality which he stated was north-west of Payaywa, and which must lie below the "C" horizon. The Headman of the village also handed me a specimen of the same species, which he stated had been found in the Man stream close to his village. Owing to the pressure of other work I was unable to visit the locality myself. These shales from their stratigraphical position and general facies agreeing with Theobald's description,[1] are most probably equivalent to the Sitsayan shales of the Prome district, although the country lying between the two areas has not been geologically mapped as yet, and the question must remain undecided until an examination has been made.

"The Sitsayan shales, if we may provisionally so describe the beds alluded to above, are underlain by a series of massive sandstones alternating with shale beds, containing in the upper part (Beds D, E, and F) a Nari, and in the lower beds (Beds G, H, I, J) a Khirthar fauna. There appears to be parallelism of strike and dip between the two series, but the absence of fossils belonging to the Upper Khirthar or to the Tongrian and Bartonian periods seems to hint at the possibility of an unconformity between the Nari beds and the Eocene.

"If such unconformity exists, it may be compared to that between the Nari and the Khirthar in North-west India. Stuart[2] also has recently described an unconformity below the Sitsayan shales in the Prome area. I am unable to do more than draw the boundary between the Pegu and the Eocene by an approximate line, since there does not appear to be any lithological difference between the rocks of Nari age and those of the Eocene near the boundary; I have therefore been entirely dependent upon fossil evidence.

"The following is a list of the species from beds D, E and F which I have referred to as being of Nari age:—

"The bed marked "D" on the map contains a *Vicarya* allied to, but apparently differing in ornamentation from, *V. verneuili* d'Arch., fragments of *Ostræa*, some large *Ampullinæ*, and *Cardita* sp. cf. *mutabilis*.

"Bed E. contains—
Turritella sp. cf. kalænsis Coss.
Corbula subexarata. d'Arch.

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[1] *Mem. Geol. Surv. Ind.*, X, p. 269, (1873).
[2] *Rec. Geol. Surv. Ind.*, Vol. XXXVIII, p. 262, (1909-10).

Donax sp.
Cardita sp.

and others, not yet identified.

Bed F. contains :—

Cardita sp. cf. keyserlingi d'Arch. and Haime.
Venus granosa Sow.
Turbo sp. cf. pendjabensis d'A. and H.
Vermetus javanus Martin.
Surcula sp. cf. voyseyi d'A. and H.
Trochus sp. cf. cognatus Sow.
Strombus sp.
Natica sp.
Ficula sp.
Cassis sp.

From the fossil-bed between the 27th and 28th milestones on the Minbu (20° 10′; 94° 55′)—Ngape (20° 5′; 94° 28′) road I obtained an échinoid too damaged for accurate determination, but very closely resembling *Euspatangus rostratus* D'Arch. and *Tellina* sp. cf. *protocandida* Nœtl. The former species is of Nari age.[1]

South-west of Thanbayagaing, above the "G" horizon (which is of middle Khirthar age, and will be described below) a bed of badly preserved echinoids occurs, the prevailing genus being *Clypeaster.* My colleague Dr. G. E. Pilgrim has examined these specimens and recognises them as of Nari age. This locality being in fairly close proximity to the "G.2" locality (which contains *Velates schmideliana*, and is of middle Khirthar age) and being stratigraphically just above it, is fairly strong evidence in favour of an unconformity between the Pegus and the Eocene, since there is hardly room for rocks of Upper Khirthar or Bartonian ages to exist between the two horizons".

At the fossil bed (see map) half way between "G.2" and Padaung village the following were found :—

Oliva sp.
Ficula sp.
Solarium sp.
Cypræa sp. cf. *obesa* Desh.
Tellina sp.

The fossils from this bed give no definite evidence of age. A loose fragment of rock containing *Operculina* was found near this bed on the hill-side.

Sequence west of Padaung.

The Shwezettaw sandstones west of Padaung consist of an alternating series of rocks in which sandstones predominate; shelly and limy bands occur in the series and also efflorescent sandstones and in some of the water holes in the series there is a strong smell of sulphuretted hydrogen. Three-quarters of a mile west of Padaung there is a well-marked unconformity which I regard as of only local significance as a little lower in the sequence another one occurs.

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[1] Vredenburg :—Tertiary system in Sind, *Rec. Geol. Surv. Ind.*, XXXIV, p. 189, (1906).

Mr. S. Rama Rau's descriptions of Man *chaung* section.

In describing the Tertiary beds of this Man *chaung* sections in his progress report for the 1909-10 field season, Mr. Sethu Rama Rau states he was able to identify eight continuous fossil beds and gives their characteristic fossils and age as determined by Cotter as follows:—(in descending order).

	Characteristic fossil.		
Bed A.	*Olivia sp.*	Nari	Miocene.
B.	*Hemiaster sp.* *Nucula sp.*	Nari	
C.	*Schizaster sp.* *Heterostegina sp.* *Lepidocyclina sp.*	Nari	Oligocene.
D.	*Vicarya sp.*	Nari	
E.	*Donax sp.*	Nari	
F.	*Turbo sp.*	Nari	
G.	*Operculina sp.* *Orthophragmina sp.*	Khirthar	Eocene.
H.	....		
I.	*Nummulites beaumonti* *Nummulites vredenburgi.*	Khirthar.	

The general dips in the vicinity of the beds are given as follows by the same authority:—

Near Bed A	28°—30°
Near Bed B	30°—32°
Near Bed C	40°—42°
Near Bed E. F. G. I.	45°—48°

Mr. Sethu Rama Rau thought the change of dip between Beds B. and C. indicated an unconformity, as the beds could be traced quite a long distance along their strikes, and in all sections this sudden change was observable.

Base of Pegus Sheet 113.

Southwards in Sheet 113 (84 I/9 and 13), two thick sandstones separated by shaly strata, can be recognised at the base of the Pegu system. These probably correspond to the Shwezettaws north of the Man river. In the upper sandy band of this series on the Magyisan (19° 57′; 94° 42′) road, one mile south of Kyaukpe (19° 59′;

94° 41′), fragmentary fossils occur. South-west of Magyisan about 800 feet of shales overlie the basal sandstones of the Pegu system. A thin band of sandstones overlies these shales and then blue shales occur to the confluence just over half a mile south-west of Magyisan, where the upper sandstone band mentioned above is met. Unfossiliferous shales overlie this latter band and continue to east of Magyisan. One mile south-east of Magyisan, Dalton (*ibid*) reports the following assemblage in light blue clays in beds dipping north-east.

Operculina Hardiei (?) D'A. and H.
Paracyathus sp.
Corbula harpa D'A. and H.
Dolium sp.
Pleurotoma Stoppanii (?) Desh.

From one mile south of Magyisan, Dalton collected *Ampullina grossa*, var. *oblonga* Desh. and in Yengadin *chaung*, two miles south by east from Magyisan the following:—

Nummulites sp.
Arca manensis sp. nov.
Ampullina spherica (?) Desh.
Natica sp. cf. *N. obscura* J. de C. Sowerby.
Ceritheum sp. cf. *Vicarya Verneuili* D'Arch.
Conus sp.
Ceritheum fragments.

The last locality of Dalton's is probably the upper-most bed of the Eocene near Tabingyo (19° 55′; 94° 55′) village. East of Magyisan, shales predominate throughout the Pegu system and dip at 30° E. 20° N. The interbanded sandstones rarely exceed 20 feet in thickness, whilst limy bands in the series rarely exceed one foot. Blue clays probably occur in the proportion of three to one of other strata, and it becomes impossible to delineate the Padaung clays. The low ridges which strike south-south-east are generally formed by the thicker of the sandstone bands.

Shaly nature of whole of Pegu series east of Magyisan.

From a ferruginous band in shaly strata two hundred feet below the Irrawaddy-Pegu boundary one and a half miles north of Kayugan (19° 57′; 94° 45′), Mr. Sethu Rama Rau collected specimens of *Solarium* sp., *Conus* sp. *Dendrophyllia* spp. and other corals. The dips of the rocks decrease eastwards from the Pegu-Eocene to the Irrawaddy-Pegu boundary.

East by north of Myegya (19° 53′ ; 94° 44′) a similar series of rocks is encountered ; a shelly sandstone containing *Cardium* sp. and *Ostrea* sp. dips N. E. by E. at 10° and forms the ridge just over two miles east-north-east of the village. The whole country is flat and featureless and characterised throughout by shales reinforced by sandy bands. Where sandstone reinforcements are more fully developed, dissected ridges, striking with the rocks occur. Outcrops of rock are conspicuously absent and even the basal beds of the overlying Irrawaddians to the south-south-west are very ill-defined and the boundary consists of a fairly low pebble-capped ridge underlain by Pegu shales.

Local sanding up of Pegus towards Kyaukpon.

West of Kyaukpon (19° 50′ ; 94° 46′), the basal Pegu beds become more sandy, and occur as a series of fawn coloured sandstones, having, at the base, a yellow, shelly, finegrained grit. The band is over three feet thick and persists towards the south ; the shell fragments are minute and the band is characterised by small corals. East of Kyaukpon, this sanding up of the Pegus is continued in the higher horizons in alternating sandstones and shales. In the stream due east of Nga-aing (19° 52′ ; 94° 49′), massive light fawn coloured sandstones showing false bedding and local unconformities dip 25° north-east. At their base is a shelly band characterised by *Pectens* and below this shales. Shales also characterise the Yethahla (19° 45′ ; 94° 52′) valley to the south and continue higher in the series to west of Mindegale (19° 44′ ; 94° 54′). They are soft, blue, and splintery. Three hundred yards west of Mindegale, a fossiliferous horizon contains *Ostrea* sp., *Pecten* sp. and corals and dips north-east ; eastwards and higher in the sequence the Pegu system becomes sandy, and soft, fawn (curry powder colour when wet) sandstones dip in the same direction at low angles (10°—20°) ; false-bedding becomes common, and hard flaggy sandstones occasionally ripple-marked reinforce the softer series. This fawn-coloured sandstone is capped by red earth with included conglomerates at the Pegu-Irrawaddy boundary. One mile due east of Mindegale, where a stream cuts through the boundary a well-marked local unconformity occurs.

The shales of the Yethahla valley pass gradually down into an alternating series of shales with soft sandstone reinforcements, and becomes predominantly sandy just above the Eocene boundary.

Upper sandy, middle shaly and lower sandy nature of Pegus at Yethahla.

Exposures in the shaly series are rare even in the streams and in places the *nalas* are lost where dams have been built to provide paddy cultivation. This sequence of sandy strata underlying the Irrawaddy-Pegu boundary and overlying the Pegu-Eocene boundary, with a shaly series in the middle, continues south-south-east to Talokyin (19° 34½′; 94° 57′).

Development of Okhmintaung ridge sandstones.

In the Tiyo (19° 32′; 94° 57′) valley to the south a thick band of blue shales overlies the alternating strata of the Pegu-Eocene boundary. Above this shaly series, north-east of Paungkadaw (19° 30′; 94° 57′), is a sandy one which forms the Okhmintaung ridge. The shales of the valley pass upwards into shaly, crumbly, blue sandstones, which weather conchoidally, and the latter into a blue unfossiliferous sandstone series, in which harder bands form falls in the *nalas* up to 50 feet in height. Above these are shelly sandstones alternating with soft fawn sandstones or shales. A fossil band at the summit of the ridge contains—

Melongena acanthina, Dalt.
Pecten sp.
Dione dubiosa.
Dosinia protojuvenilis.
Turritella angulata (2 ribbed form).

These Okhmintaung ridge sandstones pass upwards into shales of the Shwebangaing valley, in which, a quarter of a mile west of Shwebangaing village (19° 3′; 94° 58′), is a fault on a N. 15° W. strike.

Faulted boundary of Eocene and Pegus south of Talokyin.

The dip of the sandstones east of Paungkadaw is E. 10° N. at about 20°. To the north the dip steepens to about 35° and the strike swings to N. 30° W. A fault separates the Okhmintaung ridge sandstones which are of Singu age, from the Eocene ridges to the immediate west; the fault runs north by east along the line of the streams which the Tiyo-Talokyin path follows. Faulting also occurs in the Eocene rocks to the north, where contortion is seen in the carbonaceous shale series. It also occurs in the Pegus at the base of the upper sandy series, one mile east by north of Pyinbinzan (19° 38′; 94° 56′). The latter fault strikes N. 20° W. and continues south-wards just west of Pt. 941. It is indicated in Pyinbinzan *chaung* by a zone of very broken sandstone and shale strata.

Shales of Paungkadaw Valley.

Southwards from Paungkadaw to Paungganaing (19° 29'; 94° 47') and Pungyi (19° 27'; 94° 57½') the whole valley between the main Eocene ridges to the west and the Okhmintaung ridge to the east is occupied by crumbly blue sandy shales which pass downwards towards the west first into fine-grained sandstones and then as the dip steepens towards the summit of the ridge into a harder series. Lying above these valley shales are the alternating soft fawn shelly sandstones of the Okhmintaung ridge. To the south these sandstones become softer; more shale bands occur in them and they dip at less steep angles. As a consequence the soil cap becomes thick and the ridge as a physical feature disappears.

In the bay of Pegu rocks four miles north-west by west of Kyaukkyi on the western side of the Eocene ridge, the sequence owing to the jungle, thick soil cap and broken featureless country cannot be made out with any degree of accuracy. The strata overlying the Eocene boundary due west of Kyaukkyi (19° 20'; 94° 59') are certainly very shaly where they can be seen in the stream sections, and also due south of Didubin (19° 23'; 95° 0') to the north of Kyaukkyi, although a band of massive sandstone occurs in the latter shales about half a mile due south of the latter village. Eastwards from Didubin, these shaly strata pass into alternating strata of fine fawn sandstones and blue shales which dip at from 70°-80° E. 20° N. to the fault which strikes N. 20° W. across Daungbyan *chaung* immediately west of Pinmakan (19° 23'; 95° 1'). To the east of the fault the strata are horizontal and grade upwards into soft fawn sandstones. Near Konkyaukkyi (19° 22'; 94° 5') village, sandy strata however overlie Eocene foraminiferal limestone on the Kyaukkyi—Konkyaukkyi road.

Sequence west of Kyaukkyi.

On the Thayetmyo (19° 20'; 95° 14')—Mindon (19° 21'; 94° 50') road west of Kyaukkyi, shales occur at Mile 21·4 in the bend of Pani *chaung* but give place only one furlong further west, to fossiliferous sandstone doggers, from which the following fauna was obtained :—

Cardium sp.
Arca mioensis.
Dosinia protojuvenilis.

Tapes protolirata.
Tapes sp.
Dosinia sp.
Dione sp.
Pecten sp.

Immediately north-east of Myebya (19° 22′; 94° 55′) and east of the Kyauk *chaung*—Pani *chaung* junction the following fauna was obtained from similar rocks:—

Clavilithes sp.
Conus sp.
Flabellum sp.
Cytherea sp.
Corbula sp.
Turritella sp.

At Mile 25·7 a bed of quartzose gravels, dipping 10°-15° south-east, appear to be intercalated in shaly sandstones and shales. To the west this alternating series is underlain at Mile 26·7 by fine shaly sandstones with harder lenticles which dip east by south at 15° and the latter at Mile 27·4 by shaly sandy strata. Gravels occur sporadically all along the Pani *chaung* valley, and, in the synclines further north, are associated with ferruginous red earth very like that occurring along the basal Irrawaddian boundary in the main Irrawaddian outcrop to the east.

Pegu series east of Thakutkyaw.

On the summit of Hill 786, one and a quarter miles east by north of Thakutkyaw (19° 18′; 94° 56′) fine-grained grey, limy, sandstones overly the shales of the valley to the west. In the sandstone series which dip north-east at 55°, are included rather coarse glauconitic types and a soft sandstone crowded with the multi-ribbed form of *Turritella*. To the south-east on the Chaungmagyi *chaung* one and three quarter miles east by south of Thakutkyaw, a hard fairly coarse grey limy grit dips N. E. by E. at 47°. Shales with soft sandy bands overly this grit down-stream and dip at 35° in the same direction. Harder flaggy bands then occur in a shale series and are followed by soft, blue sandstones with harder limy lenses 3′-6′ in diameter which weather unevenly. These soft sandstones are efflorescent and fairly thick, and, west of the junction a mile north of Pyinaing (19° 17′; 94° 56′), contain typical Pegu fossils (*Conus*, *Pecten*. *Cardium*, *Arca* etc.) in a three-foot band of fossil conglomerate. The soft sandstones then become more shaly and pass upwards into the band of blue shales which underlie the Pyinaing-Satle (19° 16′; 94° 57′) valley.

Sandstones Theobyit Taung Ridge: (19° 16′; 94° 55′).

A mile and a quarter south-east of Thakutkyaw, Eocene shales are separated by a cross fault from a sandstone series to the south. Rocks of the latter series dip E. 10° N. at 70° on the summit of the scarp of the Theobyit *Taung* ridge, where a hard band of shelly limestone is crowded with the multi-ribbed form of *Turritella*. These *Turritella* sandstones are correlated with the similar ones found on the ridge, one and a third miles to the N. E. by N. being separated from them by the cross fault mentioned, as, from where the ascent steepens on the northern slopes of the Theobyit *Taung* ridge (19° 16′; 94° 55′), southwards, no Eocene limestone bands were found on the same line of strike. The shelly limestone afore-mentioned on the summit of the scarp gives place to the south to hard sandstone weathering down joints and giving castellated effects. Eastwards the dip lessens to 60° in hard fawn sandstones, the dip slopes of which series are bare and lacking in vegetation except for a few struggling bamboo clumps in the joints and fissures. The stream beds make use of the joints of the rocks and cut down in a series of rock chimneys exceedingly hazardous to traverse.

Towards the base of the slope the sandstones become soft and grade upwards into the shales reinforced by occasional bands of fine-grained sandstones of the Pyinaing valley. The sandstones series of the Theobyit *Taung* ridge is the same as that which forms the scarp on which the Shwenattaung Pagoda (19° 16′; 94° 53′) is situated.

Further south, three-quarters of a mile due west of Kazunmyaung (19° 15¼′; 94° 57′), big lenses of harder fine fawn sandstones underlie the shale series of the Kazunmyaung-Satle valley. They dip E. 20° N. at 45° and pass westwards into massive sandstones. These latter sandstones are intercalated with softer bands and stand out as a series of dip and scarp slopes bare of vegetation; they continue to the summit of the ridge, which is bifid, and it is the more westerly branch which continues to Myitmyin *Taung* (19° 14′; 94° 56′) to the south. In this sandstone series, fossils occur and at a height of 1,100 feet, south east of Theobyit *Taung* peak and for some distance below, casts of gastropods were noted in the more limy bands. Where these sandstones have weathered, all the lime of the fossils has been leached out and only casts are left; where unweathered the sandstones are so limy and hard that the tests fracture on extraction.

West of Aukmanein (19° 14′; 94° 57′), a series of blue shales grading to soft fine sandstones with irregularly weathering lenticles, are seen in the tributary stream to the Aukmanein *chaung*. The dip appears to be E. 14° S. at about 43° but the bedding is very irregular. In the stream, blocks of sandstone contain the multi-ribbed form of *Turritella angulata*. Westwards are fine fairly hard greyish sandstones of massive character; they form a series of small water-falls and contain, further west, some well-bedded bands dipping E. 5° N. at 70°. On the 'col' at the top of the ridge, only debris of fine fawn *Turritella* sandstones occur and they continue south along the summit to Myitmyin *Taung*, whence irregularly bedded and jointed sandstones continue practically to Mindon *chaung*, where a fossiliferous band containing *Turritella* dips east at very low angles. Eastwards along the Mindon *chaung*, similar bluish, irregularly-bedded sandstones dip E. 25° S. at 35°, whilst half a mile northwest of Singaw (19° 13′; 94° 57′) police station, a fawn sandstone contains all forms of *Turritella angulata* (Sow). The same sandstone, half a mile further north, is crowded with the same species together with a species of *Natica*. Singaw village is situated on shales which occur to east of Myohla (19° 13′; 94° 57′) where sandstones overlie them. These sandstones are alternating hard and soft fossiliferous ones and have occasional shale intercalations. They can be traced to Kama and are co-extensive with the Prome sandstones as mapped in that area by Murray Stuart. They are overlain on the Mon *chaung* to the east of Myohla by softish fawn unfossiliferous sandstones which grade occasionally into shales. The best fauna from them was obtained from a three-foot band of fawn homogeneous micaceous sandstone towards the base of the series, on the Mindon *chaung*, about half a mile due east of Myohla village.

Sequence in Singaw area (19° 13′; 94° 57′).

The following Kama faunas were collected from the series one-third and one-half miles east of Myohla respectively.

(1) *From one-third mile east of Myohla.*—

Arca mioensis.
Cardium sp.
Solarium cf. *maximum* Noetl.
Tapes protolirata.

Dione cf. *Arrakanensis.*
Solen sp.
Dosinia protojuvenilis.
Dione dubiosa.
Corbula prototortuosum cf. *Corbula socialis* Martin.
Fusus sp.
Arca sp.
Tellina Hilli Noetl.
Dione protophillipinum

(2) *From one-half mile east of Myohla*—

Dendrophyllia sp.
Ostrea papyracea.
Dione protphillipinum var. elongata, var. *obicularis.*
Tapes protolirata.
Dosinia protojuvenilis.
Tellina pseudohilli.
Cardium protosubrugosum.
Arca Burnesi.
Crytospira Burmanica Vred.
Clavilithes seminudus.
Terebra (*Myurella*) *Oldhami* Vred.
Oliva tjidamarensis Mart.
Solarium maximum Philipp.
Surcula Thangaensis Vred.
Natica sp.
Terebrum cf. *protoduplicatum* Noet.
Terebra sp.
Conus sp.
Surcula sp. cf. *Sethuramae* Vred.
Corbula cf. *socialis* Mart. and *prototruncata* Noetl.

Rocks of lower part of Pegu system, Mindon *chaung*.

Up the Mindon *chaung* three miles west of Letpwa (19° 14′; 94° 54′), a sandstone series with harder lenticles dips south-east by south at 40°. In this series just over a quarter of a mile east of the junction, a reef of foraminifera dips E. 30° S. at 20° and is exposed along the track for about 350 yards. The foraminifera are *Lepidocyclinae* and are of Oligocene age. In the descent to Lebya (19° 14′; 94° 52½′) along this track the solid geology is obscured by gravels sometimes cemented to ferruginous conglomerate. The Lebya valley is underlain by a lenticular sandy series which dips east by south at 35°.

East by north of Leye (19° 16′ ; 94° 52½′) on the left bank of the Mindon *chaung*, shaly sandstones with shale intercalations dip down-stream at 30°, whilst lower down stream above the village of Hmaik (19° 15′ ; 94° 53′), sandstones, with harder lenticles, dip south-east at 30°, and weather spheroidally after the manner of closely compacted homogeneous shales. Thereafter southwards to Letpwa sandy strata dip E. 25° S. at 15°.

Letpwa area (19° 14′ ; 94° 54′).

Just above Letpwa village in shaly sandstones is a fossil band containing a *Melongena* fauna. The same series continues to the north-east where it is occasionally covered by gravels. It dips at low angles (10°) in a southerly direction, steepening in the stream nearly a mile north-east of Letpwa, where massive sandstones with harder lenticles occur. The stream passes through narrow joints in this series, and strings of pot-holes are common, especially where doggers have weathered out. *Turritella sp.* and *Pecten sp.* occur in these rocks which belong to the middle sandstone series of the system.

Further to the north-east on the west side of the valley which runs N. N. W. to Thakutkyaw (19° 18′ ; 94° 56′) vertical shaly strata with marly bands occur ; they strike N. W.-S. E. and appear to be in the same zone of crushing as was noted further to the north-west, on the Thakutkyaw-Leye and Kinbongaing-Thambula tracks.

Chinhnit area (19° 12′ ; 94° 55′).

Half a mile south-east of the village of Letpwa, a bedded series of lenticular sandstones dips N. E. by E. at 20°. The lenses in the series are composed of fine grey limy, and the remainder of fine blue micaceous sandstone. The series exposed on the left bank of the river is from 200-300 feet thick and entirely unfossiliferous. Westwards, similar blue soft sandstones which dip in the same direction, occur. The dips where this series is massive and not too well-exposed are difficult to determine owing to weathering along joints. Eastwards, where seen one mile east by south of Letpwa, the dip of this series becomes gentler under the villages of Kandwin (19° 13′ ; 94° 54′) and Chinhnit (19° 12′ ; 94° 55′).

North-west of Chinhnit, unconsolidated quartz gravels and axial detritus, the boulders of which attain 12″ in diameter, crown the ridge which separates Chinhnit from Kandwin village at a height of about 200 feet above the level of Mindon *chaung*. West by south from Kandwin, fine micaceous sandstones with harder lenticles dip at 26° on the watershed east of the Mibauk valley. The Mibauk valley is underlain by shaly strata with occasional limy bands; at Mibauk homogeneous fine blue shales which break up into angular fragments, dip N. E. by E. at 15° in the river bed. At Pyagyi (19° 11′; 94° 53′), three miles to the south-east of Mibauk (19° 12′; 94° 52′), fine blue shales weather spheroidally and have thin intercalated limy bands which dip E. 27° N. at from 35°-40°. North-east from the latter village along the *chaung* of the same name, fine micaceous sandstone intercalations appear in the shales. After the stream junction a third of a mile north-east of Pyagyi, the series becomes more sandy still, and fine fawn bluish sandstones give place to massive hard ones which cut across the *chaung* and dip north-east at 20°. These sandstones are some hundreds of feet thick and similar to the Theobyit *Taung* series. The stream whose bed and steep sides are very considerably potholed, passes through them in a series of joints. Where the valley opens out again further to the north-east, the dip flattens to 10°. Major joints on the dip slope follow a N. E.-S. W. strike. A series of alternating soft and hard sandstones continues down the *chaung*, in which, below the Pyagyi-Chinhnit stream junction, blocks of *Turritella* sandstone were noted in the bed of the stream. Soft well bedded fine-grained sand stones overlying more massive, irregularly bedded, lenticular, sandstones also occur. (Plate 12, figure 2.)

In the stream bed one and a half miles due south of Chinhnit village, are a series of water-falls, one of which is about 30 feet in height, in practically horizontal strata. Above the fall platform is a 90-foot cliff; the top 30 feet of this is composed of fine sandstones and the lower 60 feet of sandy shales.

In the Mindon *chaung* below Chinhnit, the same fine-grained micaceous series dips first at low angles in a north by westerly direction and then to the south-east by east at about 15°; the dip steepens to over 30° to the north.

Kyaukpadaung (19° 12′; 94° 57′) to Monda (19° 8′; 94° 54′).

Half a mile south-west by west of Kyaukpadaung (19° 12′; 94° 57′) alternating fine-grained fawn sandstones and shaly strata dip 30° E. 10° N. whilst half a mile further along the track in a cutting on the bank of Sadon *chaung*, in alternating hard and soft fine-grained sandstones the dip steepens to 65° N. E. by E. Where Sadon *chaung* turns S. E. by S. shales are met. The dips in these shales vary from an estimated one of E. 22° N. at 30° to horizontal; the shales are fine-grained, blue in colour, and weather conchoidally, and in the meanderings of the *chaung*, cliffs of shales 40 feet high are common. Towards the end of this shale valley, the dips steepen, and where the Kaingyimaung (19° 9′; 94° 59′) track takes off the shales dip E. 30° N. at about 60°. West along the Mataungda (19° 8′; 94° 56′) track the shales are rather sandy and micaceous and dip W. 30° S. at about 75°; they pass into fine-grained fawn micaceous sandstones on the watershed. Towards Mataungda the soil cap is very thick and the strata probably consist of shales and fine-grained shaly sandstones. Immediately north of Mataungda a micaceous sandstone dips south-east at 15° and from there up the *chaung* to the acute angled bend one mile east of Monda, shales and shaly sandstones dip at about 20° south-east.

Monda area (19° 8′; 94° 54′).

About one and a quarter miles north-east of Monda, a thick band of fine-grained bluish micaceous sandstone dips E. 15° N. at 30°. This passes into fine-grained fawn micaceous lenticular sandstone dipping S. E. by E. at 15° in Mataungda *chaung* to the south-east. The stream meanders south over this series in a bewildering fashion, possibly following joints. Close to Monda *chaung* it sands up and fragmentary fossil bands occur in it. Shales and shaly sandstones dip E. 18° N. at 30° along the track from Mibauk to Pyagyi, whilst from the latter village to Monda, the same series probably occur, but the soil cap is very thick and no bedded rocks can be seen.

From the junction of Monda *chaung*, one mile east of Monda south-westwards along the southern branch, very fine shaly sandstones dip south-east at low angles and weather spheroidally. They become shaly to the south-west and there is a fair amount of vein calcite in the *chaung* bed. This shaly series persists to three-quarters of a mile south by west of Monda, where intercalated limy bands dip south-east at 30° and at 40° where a small fault crosses the *chaung* in a S. 15° E. direction and displaces the strata a distance of 12 feet. The same alternating series continues up-stream to one mile S. W. by S. of Monda where a 20-foot band of Eocene foraminiferal limestone occurs on the south bank in strata dipping S. E. at 48°.

On Kyein *Taung*, S. E. by S. of Monda, fine-grained blue micaceous sandstones dip E. 30° N. at 30°; a similar series both with and without doggers occurs on the steep northern slope of the hill where calcareous tufa is occasionally found. No foraminiferal limestone was found either *in situ* or as debris, but in the same series in Mataungda *chaung* to the north-east, gritty bands with comminuted shell fragments occur.

Gyinye area.

Half a mile south-east of Gyinye (19° 6'; 94° 54'), fine-grained blue micaceous sandstone intercalated in softer and more shaly types, dips north-east at 40° and passes eastwards in Gyinye *chaung* into a series in which the sandstones become more dominant. Further down the *chaung* the series becomes shaly again with harder sandy bands, limy concretions and a little gypsum, whilst the dip has changed to E. 35° N. at about 35°. There is a fair amount of vein calcite in the *chaung* about one and a quarter miles east of Gyinye and thereafter the stream meanders to its junction with Monda *chaung* where fine-grained bluish micaceous sandstones with more shaly bands dip E. 30° N. at 30°. From here up Monda *chaung* to Mataungda practically horizontal fine-grained bluish micaceous sandstones with doggers occur. Where the doggers weather out big pot-holes are formed and in places the lines of doggers do not coincide with the bedding. Weathering along joints is common, and owing to this, the irregularly occurring doggers, and the massive and homogeneous nature of the sandstones, great difficulty is often found in observing the direction of dip of the bedding.

Yebokkale area.

In the *chaung* half a mile north-west of Yebokkale (19° 5'; 94° 55'), shales dip E. 5° N. at 40° and continue down the *chaung* to the hamlet, where a few harder bands occur and the dip changes to E. 25° N. at the same angle. Half a mile south-east of the village, where the stream cuts through a small range of hills, these shales with harder limy laminations give place to fine-grained blue micaceous banded and bedded sandstones, and the stream falls 20 feet down them over a dip slope. Sandy unfossiliferous shales, weathering spheroidally, succeed the aforementioned and continue to Thapangyo (19° 5'; 94° 57'), where, in Monda *chaung*, they dip N. E. by E. at 30°. Occasionally more sandy and limy bands occur in the series, which passes northwards on the ridge half a mile due north of Taungnyo (19° 6';

Taungyo area.

94° 58′) into fine-grained massive blue micaceous sandstones. Similar rocks occur east of Taungyo and dip at 20° E. 25° N., but become horizontal at the site of the village itself, whilst half a mile N. N. E. of Taungyo, they dip S. W. by W. at 60° until the dip changes suddenly to horizontal, south-east by south of Taungyo village. From where Taungyo *chaung* joins Monda *chaung*, upstream to Thapangyo, the same series continues, the dip steepening from N. E. by E. at 15° at the junction to 30° at Thapangyo. Just over half a mile west of Kyaukme (19° 1′; 94° 59′), a band of fine micaceous sandstones containing harder limy lenses dips E. 35° N. at 53°; they are similar to those of the Monda and Chinhnit areas.

One mile north by east of Peinnekwin (19° 3′; 94° 58′), soft shaly blue sandstones with harder bands dip E. 30° N. at 40°; they pass eastwards to Monda *chaung*, which, on its south-easterly course runs mainly along their strike; where occasionally it cuts across them, pools are invariably found. The dip decreases to 30° N. E. by E. as one passes up in the sequence and down the *chaung*.

Similar rocks are found forming the hills one mile due east of Peinnekwin, but become more shaly towards the Peinnekwin shale valley. South-eastwards the Kyaukme valley consists mostly of shaly strata some of which are well exposed in the bank of Made *chaung* due north of Kyaukme (19° 1′; 94° 59′) village (Plate 14, figure 1). Sandstones overlie them in the gorge to the east. Further east and immediately south of Aleywa village, shales and shaly sandstones, the hard bands with doggers, similar to the rocks seen in Monda *chaung*, dip E. 30° N. at 55°.

CHAPTER X.—DETAILED DESCRIPTION OF ROCKS. THE PEGU SYSTEM—*contd.*

The Pegu rocks of the Minbu anticline have been described in detail by Pascoe[1] and the mapping where left off by Pascoe, was continued south by Cotter and Sethu Rama Rau. The latter carried out surveys in Sheet 113 and thence south-eastwards and south into Sheets 157 and 158.

Padidaung-Kyidaung ranges.

In Sheet 113 Pegu rocks form the Tagaing (19° 56′; 94° 59′) *Taung* and in Sheet 157 the Padidaung (19° 50′; 95° 3′)—Tamansan *Taung* (19° 48′; 95° 6′)—Kyidaung range (19° 47′; 95° 7′). These hill ranges correspond with an anticlinal fold and are, according to Sethu Rama Rau, made up of steeply inclined alternating Pegu sandstones and shales forming regular scarp and dip slopes inclined at angles of from 40°—45°. The actual crest of the anticline in the south occurs in a median valley composed of shaly strata, occupied in Sheet 157 by the Kyaukmyaung and Padin *chaungs*, two tributaries of the Padi *chaung*. Shales characterise the lowest beds exposed and sandstones the upper ones.

Uppermost Pegu beds Shaukpingin.

Calcareous fossiliferous beds occur in the uppermost Pegu rocks of the area. One of these situated from 75—100 feet below the Irrawaddy boundary two miles north-west of Shaukpingin (19° 56′; 95° 1′) contains an abundance of *Arca*; it forms the highest marine bed in the area and is very constant in its occurrence. Vredenburg identified the characteristic *Arca* of the bed as *Arca rhombea* and with it *Telescopium subtrochleare.*

Tagaing-Padidaung anticline.

The main Tagaing-Padidaung anticline of the area is asymmetrical in the north but becomes more symmetrical to the south. It is not a continuation of the Minbu anticline which pitches out suddenly on Tazat *chaung* (latitude 19° 59′) where the country is all very much faulted and folded into minor plications, but forms a parallel fold to the south-west *en échelon* with it. Owing to jungle and the thick soil cap it is not possible to locate this faulting on the one-inch scale map. The asymmetrical nature of the northern part of the

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[1] Mem. Geol. Surv. Ind., XL, p. 168, (1912).

Tagaing-Padidaung anticline differs from that of Minbu in that it is the western which is the steeply dipping and faulted flank.

To the south-east in Sheet 157, where the fold is almost symmetrical, the dips of the rocks on the eastern flank can be observed between Thabyedaw (19° 52′; 95° 10′) and Sidaing (19° 49′; 95° 8′). At the former village the rocks dip 8° N. E. and steepen gradually to 30° N. N. E. at Sidaing. From Sidaing to the south-west the increase of dip is sudden to the crest of the anticline.

North of Thabyedaw the Irrawaddy river appears to occupy a syncline in the Pegu rocks, as another anticline occurs to the east of Migyaungye (19° 54′; 95° 9′) on the east bank of the river.

Mindegyi-Kyawdo fold.

West of the southerly end of the Tagaing anticline occurs the Mindegyi (19° 48′; 94° 59′) anticline in Sheet 113. This anticline strikes S. 30°—35° E. from where it pitches out north of Mindegyi, south to Kyawdo (19° 45′; 95° 0′). According to Mr. Sethu Rama Rau this anticline is symmetrical; the crest passes half a mile west of Mindegyi and immediately west of Kyawdo and rocks of the upper division of the Pegus are exposed in it. Low dips on the crest increase to 25° W. 25° S and 25° E. 25° N. on the flanks at the Pegu-Irrawaddy boundary Between this anticline and that of Padidaung is a faulted syncline in which normal dips occur between Kanyingyi (19° 47′; 95° 1′) and Nyaungwaing (19° 48′; 95° 52′) two miles to the north-east and abnormal dips near Siywa (19° 46′; 95° 3′) to the E. S. E.

To the south eastward, Sheet 158 apparently consists of a series of closely packed and very much faulted anticlines and synclines of alternating strata of Pegu age. The series is all marine and includes both hard and soft argillaceous limy strata, and in the hard limy strata, fossils occur. The sandstones are of a brownish tint and very friable; the shales are of a steel blue colour, and, being easily weathered, form valleys which support a luxuriant vegetation of bamboo, whilst rice is also cultivated in them. It is the harder limy bands which form the anticlinal hill ranges of the area. Away from the actual anticlines, the dips of the rocks are very discordant, and it was only possible for Mr. Sethu Rama Rau on the old one-inch scale map, to correlate the various rock series encountered in a general way. The general strike of the rocks is N. W.-S. E. in the north of the area and N.-S. in the south.

Kyawdo (19° 45′ ; 95° 0′)-Samaing (19° 43′ ; 95° 3′) anticline.

In the north-west corner of the sheet the Kyawdo-Samaing anticline forms, according to Mr. Sethu Rama Rau, a continuation of the Mindegyi fold previously mentioned. The general direction of the axis is E. 30° S; it is asymmetrical, the axis hading to the west. Near the crest on the westerly flank the beds dip at an angle of 10°; on the opposite flank the steepest dips registered were from 30°—35°; the crest pitches out to the south-east near Samaing village.

Kalanzin anticline (19° 44′ ; 95° 5′).

Two miles to the west of the former occurs a minor fold called by Mr. Rau, the Kalanzin anticline. It lies to the south-west of Kalanzin village, strikes S. 30° E. and persists for about one and a half miles pitching out steeply at both ends.

Chaungtha anticline (19° 43′ ; 95° 8′).

The Chaungtha anticline runs E. 40° S. from Chaungtha and is traceable for a distance of more than six miles. The southern area sinks steeply north by west of Sulegon (19° 36′; 95° 11′). It is symmetrical and the steepest dips exposed on the flanks are from 35°--40°.

Yinaing (19° 40′ ; 95° 5′) anticline.

The axis of the asymmetrical Yinaing anticline runs S. 35° E. Dips noted on the westerly, gently dipping flank near the crest were 10° and on the easterly flank 35° (Plate 14, figure 2). The crest is well-exposed for a distance of from two to three miles and pitches out gradually in each direction.

Monatkon (19° 32′ 95° 3′) anticline.

In the south-eastern corner of the sheet the Monatkon anticline strikes S. 10°—15° E. and pitches out to the north; to the south it has suffered from compressional forces and faulting. The northerly pitch of the anticline is not very well exposed and the dips change suddenly from north-west to east.

A thick outer band of sandstones shows up the structure well, whilst a thinner inner band can also be distinguished; shales outcrop in the centre of the dome. The anticline is asymmetrical, the axis hading to the west, whilst dips on the flanks in the outer band of sandstones west of Bawywa (19° 31′ : 95° 3′) are low (10°—15°).

From the outer band of sandstones in the stream five and a half furlongs S. W. by W. of Bawywa, the following were collected :—

Turritella angulata. Sow, 2 ribbed form.
Cytherea erycina.
Docinia protojuvenilis
Conus sp.
Dione dubiosa
Pecten sp.
Melongena acanthina Dalt.
Melongena sp.
Arca sp.

whilst from one furlong south-west of Tazigauk (19° 32′; 95° 2′) the following :—

Melongena sp.
Turritella angulata Sow. 2 ribbed form.
Conus sp.
Arca sp.

The fauna appears to be of Singu age and similar to that of the sandstones of the Okhmintaung ridge in Sheet 114 to the west, and from which it is separated by the overlying shales of the Shwebangaing valley. The shales of the centre of the Monatkon dome can therefore be correlated with those of the Tiyo valley which overlie the Pegu-Eocene boundary rocks and underlie the Okhmintaung ridge sandstones.

Kyankme Area.

The Okhmintaung ridge or Monatkon sandstones rise again from beneath the shales of the Tazi *chaung* valley to the east and north-east of Monatkon, and are underlain by a thick series of shales around Kyaukme. This lower shale series also occurs in the valley one and a half miles west of Wunledaung, probably as the core of a broken anticline, as sandstones dip south-west from the apparent axis; in these sandstones the following specimens were collected in the stream a quarter of a mile south-east of Pt. 639 (19° 31′; 95° 6′)—

Turritella angulata Sow. 2 ribbed and multi-ribbed forms,
Conus sp.
Cytherea erycina.
Dione dubiosa.
Arca metabistrigata.

Tellina sp.
Dosinia protojuvenilis.

Sequence east of Lontaw.

East from Lontaw (19° 31′; 95° 8′) along the Nyaungywa (19° 32′; 95° 12′) track are blue shales. The dip steepens to 50° S. W. where a thick band of sandstones crosses the stream. Alternating strata dipping S. W. by W. follow and give rise to vertical sandstones demarcating the northern extension of the Okpon (19° 22′; 95° 14′)—Talabasan (19° 27′; 95° 10′) fault. From the fault to the ridge at Pt. 1603 the soil cap is thick and exposures rare; three quarters of a mile east of Pt. 1603, in the stream to the north of the track, much fractured grey sandy shales dip south-east at 15°. Harder calcareous and arenaceous bands in the shales to the east form water falls and the stream course becomes impassable. In the sandstone area which intervenes between the upper shales of Tazi *chaung* and the lower ones of Kyaukme and Lontaw, the strata are crowded with various forms of *Turritella angulata.*

Correction of Monelkon with anticlines to east and north-east.

Although this Monatkon area is the only part of Sheet 158 which I personally saw, it appears extremely probable that most of the other anticlines in the eastern part of the sheet consist of the same series of sandstones and shales as form the Monatkon anticline. Certainly the only fossils which Mr. Sethu Rama Rau reports from the remaining part of the area are of Singu age. Their localities as given by Mr. Sethu Rama Rau are as follows:—

(1) On the easterly flank of the Kalanzin anticline, south and north-west of Kalanzin (19° 44′; 95° 5′).
(2) On the easterly flank of the Kalanzin anticline, south-west of Tubauk (19° 45′; 95° 10′).
(3) East of Zwegyo (19° 42′; 95° 8′) and east of Shadaing (19° 36′; 95° 12′) in the synclinal valley on the west side of the Chaungtha anticline

Of this area Vredenburg[1] states:—

Vredenburg: Leplanzeik fauna.

'Along both banks of the Irrawaddy in a northern direction from Thayetmyo to Sinbaungwe (19° 43′; 95° 12′) wherever the lowest beds locally exposed become visible as the results of anticlinal structures, the late Mr. Bion and Mr. Sethu Rama Rau have recognised a highly characteristic layer distinguished by the presence of three particular species belonging to the genera *Dendrophyllia*, *Schizaster* and *Nucula*. The *Dendrophyllia* and the *Nucula* agree specifically with some fossils yielded by the lowest fossiliferous beds exposed at Singu, so that Mr. Bion and Mr. Sethu Rama Rau came to the conclusion that the oldest beds exposed in the country to the north and north-east of Thayetmyo belong to the same horizon as the oldest beds exposed at Singu. Strata approximately on the horizon of the *Dendrophyllia* bed are exposed along an anticlinal rise at Leptanzeik (19° 24′; 95° 14′) about six miles north of Thayetmyo. They have yielded three determinable Siphonostomata :—

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[1] *Rec. Geol. Surv. Ind.*, Vol. LI, p. 234, (1920).

Terebra quettensis n. sp.
Surcula fusus n. sp.
Tritonidea Martiniana n. sp.

Terebra quettensis cf. Vredenburg, a characteristic fossil of the Nari of Baluchistan is one of the commonest fossil of the Singu fauna. The extraordinary and very easily recognisable shell designated *Surcula fusus,* ...... is known from Payagyigon (20° 43′; 95° 4′) in the Gwegyo anticline of Upper Burma[1] where it occurs amidst a fauna of the Minbu type. *Tritonidea Martiniana* is one of the commonest fossils of Yenangyat, Minbu and Singu and of many other localities yielding the fauna of the oil-fields.

The Siphonostomatous fauna of Leptanzeik, scanty though it may be, is thoroughly characteristic and entirely corroborates the conclusions arrived at by Mr. Bion and Mr. Sethu Rama Rao in placing the oldest beds exposed in the anticlines upon a horizon at least as low as that of the lowest beds exposed at Singu.'

Linke area.

To the north-north-west in Sheet 114, a soft sandstone series underlies the Linke-Bwegyi Irrawaddian sandstone basin. In these soft sands immediately below the Pegu-Irrawaddian boundary two miles south of Linke (19° 41′; 94° 59′) the following fauna was collected :—

Parallelipiped protortuosum.
Turritella sp.
Conus sp.
Meretrix sp.
Cassidaria sp.
Galeodia monilifera.
Coral.

Uppermost Pegu rocks : Thayetmyo area.

In the western half of Sheet 159 near Talabasan an Irrawaddy outlier is underlain by sandstone bands some of which are brecciated and impregnated with calcite, and are followed one and half miles north-east of Tawmun by sandstones containing *Turritella angulata* (Sow). The latter are succeeded half a mile to the north-east by an inextricable mixture of green sandstones and shales in what is evidently the fault zone of the Okpo-Talabasan fracture.

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[1] Cotter, *Rec. Geol. Surv. Ind.*, Vol. XXXVI, p. 131, (1907-8); Vol. XXXVII, p. 230, (1908-9).

North-east of Thayetkyin (19° 28′; 95° 7′) the Irrawaddian boundary is demarcated by a steep scarp. West of the outlier, the Kadetpin (19° 30′; 95° 5′)—Sanmagyi (19° 27′; 95° 4′) Myinba (19° 25′; 95° 6′) valley is predominantly shaly, becoming sandy in the uppermost beds immediately underlying the Irrawaddy sandstones. In the hollow of the valley there are no exposures owing to the thick soil cap and cultivation, but the strata appear to be flat, the high ground being formed by a sandstone intercalation.

Okpo anticline.

West of this valley is the Okpon (19° 28′; 95° 3′) dome, the southern continuation of the Monatkon fold. Between the two is an area in the south-west corner of Sheet 158 and the north-west of Sheet 159 which has been very much compressed and faulted. The southerly pitch of the fold as a whole affects the southern dome, and the shales exposed in the core are not so thick as are seen further north in the Monatkon structure, nor is the inner thin band of sandstones perceptible. The outer band of sandstones shows up the structure in the northern part of the fold but south-west of Sanmagyi they swing to the south-west towards Ngabatkya (19° 25′; 95° 2′) and are overlain by shales of the Pungyaung *chaung* valley. They are represented on the western limit of the map by sandstones in Pauk *chaung*.

In the outer band of sandstones of the Okpon dome the following faunas were collected on the eastern flank.

(1) *From a quarter of a mile north-west of Okpon (19° 28′; 95° 3′).*—

Cytherea erycina.
Dosinia protojuvenilis.
Ostrea papyracea.
Dione sp.
Arca metabistrigata.
Pyrula condita Brogn var. *Singuensis* Vred.
Pyrula promensis Vred.
Tellinæ sp.

(2) *From three quarters of a mile south by east of Okpon*

Solenomya cf. *Cultellus* Mart.
Turritella angulata Sow. 1, 2 & multi-ribbed forms

(3) *From half a mile north-north-east of Okpon.*

Fusus (Clavilithes) seminudus.
Pyrula condita Brogn, var. *Singuensis* Vred.
Dione dubiosa Noet.
Corbula sp.
Tellina (Phylloda) foliacia (Reeve).
Tellina pseudohilli Noet.
Cytherea erycina Fav.
Cardita cf. *Viquesneli* D'Arch and Haime.

(4) *From three and a quarter miles south-south-east of Okpon* :—

Dosinia protojuvenilis.
Turritella angulata Sow. 2-ribbed form.
Cytherea erycina.
Flabellum sp.
Arca sp.
Conus kyudawonensis.
Galeodia monilifera.
Ostrea papyracea Noet.

From the eastern flank of the dome the following fauna was collected from just over a mile north-east of Zidaw (19° 27′ ; 95° 0′).

Cytherea erycina.
Cardita cf. protovariegata Noet.
Tellina sp.
Pecten sp.
Arca burnesi
Dosinia protojuvenilis Noet.
Conus sp.
Ostrea papyracea.

Banbyin area.

Around Banbyin (19° 25′ ; 95° 5′) on Pungyaung *chaung* are shales. West of the village they dip in an easterly direction for about half a mile, to where the crest of the broken Banywa anticline is reached. In the stream on the north bank is a band of practically horizontal soft fine-grained grey sandstone overlain by blue shales. Oil seeps out of the sandstone, into which at the time of my visit (1923) hand-dug wells were sunk.. Up the tributary to the west are shales followed to the north by alternating strata which dip south at 16°.

Local faulting south of Banbyin.

Between Banbyin and the Thayetmyo-Kyaukkyi road, very little can be made of the geological sequence owing to the flat nature of the country, the thick soil cap and the presence of small local faults. Five furlongs south of Banbyin, a band of fine-grained, fawn coloured sandstones dips 50° W. S. W., whilst a similar band dips south-west at 16° in the *chaung* east of Pegadin (19° 24′; 95° 4′). These dips are, I think, extraordinary local, and are due to small faults having very limited extensions.

In the stream north of Shanywagyaw (19° 22′ ; 95° 4′), sandstones dip S. S. W. at an average of 10°, whilst from one-third mile south-west of the village, Irrawaddy gravels are continuous to Yemyet (19° 21′ ; 95° 4′).

Taungmyin area.

Good exposures of Pegu rocks are seen along Daungbyan *chaung* north-west of Yemyet whilst a fault strikes N. 20° W., one and a quarter miles north-west of Taungmyin (19° 22′ ; 95° 2′). To the east of the fault the strata are flat and grade upwards from alternating strata into soft fawn sandstones. Westwards alternates of fawn fine-grained sandstones and blue shales dip from 70° to 80° E. 20° N. These latter are underlain in the broken ground around Didubin (19° 23′ ; 95° 0′) by shales which form the base of the Pegu system. To the south-west by north of Twinle (19° 18′ ; 95° 3′) alternating Pegu strata dip S. W. by S. and south-east under Irrawaddy sands and gravels.

Yegyi *chuang*.

On the Yegyi *chaung* crushed shaly strata occur at the boundary on the north side of the Kokkozan fault. A series of soft fawn sandstones which are underlain by thick blue shales follows and in the latter, immediately west of the Taungbogyi-Kokkosan road crossing, the following fauna was collected :—

Conus kyudawonensis.

Cardium sp.

Dosinia protojuvenilis Noet.

Corbula sp.

Conus sp.

Dione protophillipinarum Noet.

Tellina sp.

Tanlebin area.

On the east side of the [illegible]-Pyaye syncline, east of Tanlebin, (19° 20′; 95° 8′) sandstones at first dip at low angles but steepen to 72° S. W. by S. one-third of a mile from the village. They are succeeded by sandy blue shales, rather papery, and probably, much crushed. Five furlongs N. E. by E. of Tanlebin on a N. W. by N. strike, vertical fault breccia was noted and was followed down the *chaung* by a mass of broken fawn sandstones. A horizontal cliff section of 50 ft. of blue shales, reinforced by bands of limy sandstone one foot thick, and capped by ten feet of hard fawn sandstone, then occurs. To the east, an easterly dip sets in, and the stream passes over a thick band of fairly hard fawn sandstones dipping up to 55° E. 5° N. These latter are probably repeated by faulting as similar sandstones are found lower down the *chaung*. The dip then becomes gentler and soft sandstones and shales succeed the latter, and are themselves overlain by alternating fawn sandstones and silts below the Irrawaddy boundary.

The Lime Hill (Myinmagyitaung.)

To the south older strata are exposed in the rocks forming the Lime Hill (Myinmagyitaung. 1032—19° 17′; 95° 11′). This latter area was first visited by Oldham, who reported adversely on the coal which occurs in the lowest shaly series exposed in the hill; it is mentioned by Theobald[1] who described the strike faulting which has occurred and classed the limestones which outcrop as Nummulitics.

Cotter[2] describes specimens collected by Theobald purporting to come from the Lime Hill, and also specimens collected by Mr. Sethu Rama Rau from the same place.

Theobald's specimens include three species of *Orthophragmina* as well as some fragments of a *Lepidocyclina* limestone. Mr. Sethu Rama Rau's specimens included only *Lepidocyclinæ*. In Records of the Geological Survey of India, Vol. LIV, p. 112, (1922), Cotter reverts to the age of the rocks of the Lime Hill, and puts forward the possibility that Theobald's species of *Orthophragmina* came from the western part of the Thayetmyo district, where they are common, and not from the Lime Hill, where neither Romanis[3], Sethu

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[1] *Mem. Geol. Surv. Ind.*, X, p. 296, (1873).
[2] *Rec. Geol. Surv. Ind.*, XLI, p. 323, (1911).
[3] *Rec. Geol. Surv. Ind.*, XVIII, p. 149, (1885).

Rama Rau nor H. S. Bion could find any. I spent a day collecting on the Lime Hill and also found only specimens of *Lepidocyclina* and none of *Orthophragmina*. Previously (*ante* p. 178) I have expressed doubts about the origin of Theobald's Triassic specimens, and I agree with the doubts expressed by Cotter regarding Theobald's specimens from the Myinmagyitaung area.

The general structure of the Lime Hill is that of a fold-faulted anticline pitching out very steeply to the south-east and gently to the north-west. A big strike fault, to the south-west of the summit of the range, forms the western boundary of the oldest rocks exposed, and brings rocks of the uppermost sandy series of the Pegu system against them on the west side of the fault. North-eastwards from the fault a sequence of Pegu rocks is obtained. They consist of a shaly series at the base containing coal seams and massive *Lepidocyclina* limestone. These are overlain by a sandy series containing *Lepidocyclinæ* and the latter by the shaly series which underlie the uppermost sandy series below the Pegu-Irrawaddy boundary. Stratigraphically the Lower Sandy Series corresponds to the sandstones of the Monatkon and Okpon domes.

Eighteen miles due west of the Lime Hill *Lepidocyclina* sandstones occur in the lower horizons of the Shwenattaung Pagoda hill sandstones.

Pyaye anticline.

In the midst of the main Thebyu-Pyaye syncline of Irrawaddy Sandstones is the inlying anticline of Pyaye (19° 12′; 95° 12′). The Ton (19° 13′; 95° 51′)—Peikthalin (19° 15′; 95° 13′) road cuts across the anticline and on the east the highest Pegu rocks seen are fawn sandstones, which underlie Irrawaddy conglomerates and dip W. 5° S. at 40°. They continue to the east and form a prominent ridge striking N. 20° W. On the ridge summit on a bearing W. 5° S. from Peikthalin they dip 15° but to the west by south the dip steepens to 35°. East of the sandstone ridge is a deep elongated valley with a thick growth of bamboo jungle underlain by sandy shales or shaly mixed strata. This basin is bounded on the east by a range of hills composed of gravels and conglomerates dipping E. 5° N. at about 40°. North and south the anticline pitches out gently under the overlying Irrawaddy gravels.

Outcropping along the bank of the Irrawaddy river between the villages of Pyaye and Pato (19° 8′; 95° 13′) is the northern

Pyalo anticline.

extension of the Pyalo anticline. It consists of Pegu rocks which can be divided into two groups, an upper soft one consisting of unfossiliferous alternating shales and soft sands, and a lower of harder sandstones, forming the mass of the Pt. 602 hill. These are well exposed on the bank of the Irrawaddy. Vertical strata occur on the south-west side of the exposure both in the Pegus and the overlying Irrawaddy rocks. Possibly faulting has taken place along the flanks parallel with the axis, and on the south-west flank the upper more shaly group has been almost squeezed out. On the north-east the Irrawaddy river cuts into the anticline. A fossil band crowded with *Cytherea erycina* was noted half a mile north-east of Pato immediately underlying the Irrawaddy basal conglomerates.

One mile north of Damathaw (19° 7′ ; 95° 10′) on the Irrawaddy, a small hill rises steeply from the surrounding country. It is capped by basal Irrawaddy conglomerates underlain on the western side by blue shales of the uppermost Pegus of the area. Further west are more Irrawaddy conglomerates and a fault striking N. 30° W. must occur along the western flank of the hill.

Natmi anticline.

From one mile south of Subotaung (19° 8′ ; 95° 8′), north-west to the extreme north-west corner of Sheet 160, a broken anticline of Pegu rocks is exposed. The anticline pitches out to the south-east and finishes in the monoclinal structure of the Pyinaing-Myohla valley to the north-west. The rocks apparently belong to the uppermost Pegu division. Half a mile south-west of Kyattandaw (19° 9′ ; 95° 7′) soft fawn sandstones dip 40° south-west. In an easterly direction along the ridge the dip gradually lessens and after one and one-third miles becomes practically horizontal. Low dips in these sandstones cannot be relied upon owing to the lenses of harder sandstones included in them. In the upper drainage area of Inbettaw (19° 6′ ; 95° 7′) *chaung* they are overlain by blue sandy shales, which are succeeded under the Irrawaddy gravels by soft fawn laminated and false-bedded sandstones dipping 30° south-west. Immediately north of Natmidauk (19° 10′ ; 95° 7′) in a Pani river cliff section are fawn sandstones with intercalated laminated clays; a gas seepage occurs on the hill to the east in this series during the rainy season.

At the north-west corner of Kyattandaw, blue, fawn when weathered, unfossiliferous sandstones dip 15° west by south, whilst half a mile S. E. by E. of Pabut (19° 12′; 95° 6′) soft fawn sandstones dip east by north at 30°. These continue south-east down the Pani *chaung* and a flaggy band intercalated in them north of Natmi (19° 10′; 95° 7′) dips due east at 19°. North-west of Natmi unfossiliferous horizontal sandstones containing harder lenses occur. Westwards to Myinmyintaung (19° 4′; 95° 4′) the dips steepen and one-third mile to the north-east of the trigonometrical point a dip of 45° south-west was registered. On practically the same strike, half a mile N. E. by E. of Magyibin (19° 11′; 95° 3′), similar sandstones containing *Dosinia* sp., *Arca* sp., and *Cardium* sp. dip 60° south-west, and a fracture probably occurs along this line and continues in a south-easterly direction crossing Pani *chaung* south of Kyattandaw. From Myinmyintaung, north along the watershed horizontal sandstones with harder lenses prevail. West from Paukuga (19° 15′; 95° 4′), sandstones dip east and contain a fossil band crowded with *Cytherea erycina* (Noet.) and also species of *Cardium* and *Pecten*. They are followed to the south-west in the valley demarcated by cultivation, by vertical sandstones striking about 25° west of north. The junction is sharp and marks a fault.

To the south-west the dip lessens and becomes horizontal on the watershed, changing to south around Ponna (19° 13′; 95° 2′) where soft fawn sandstones, sometimes fossiliferous are exposed. In these sandstones half a mile west by north of Ponna the following were collected:—

Cytherea erycina.

Conus sp.

Arca sp.

Turritella sp.

North of Ponna along the Thazigon road, some of the Pegu sandstones are laminated red and yellow; they dip south at low angles and become horizontal further north where, after a sharp break, the dip changes to 27° N. 20° E. and becomes steeper before the Pegu rocks are obscured by Irrawaddy gravel detritus.

South west bank of Mindon *chaung*.

On the south-west bank of the Mindon *chaung* three quarters of a mile east of Linywa (19° 12′; 95° 1′) a sandy series dips 23° east. In the Kaingyimyoung *chaung* one and a half miles west of the village a thick band of blue shales dips 45° E. 30° N. It is followed eastwards by a thin band of shelly sandstone and then by more shales; thereafter only isolated exposures of sandstones dipping E. 30° N. are encountered. West of Kyimi (19° 11′; 95° 2′) in a cliff section fawn sandstones with stringers of harder lenticles and harder bands (8″) dip E. 15° N. at 22°.

Thangyo Taung ridge.

A quarter of a mile N. E. by N. of Thangyotaung (19° 6′; 95° 2′) the ridge consists of massive blue fine-grained sandstones dipping at 70°, E. 25° N. They are succeeded to the east by a softer series of similar sandstones grading in places into shales; the latter are overlain by a thick mass of blue shales continuous for three quarters of a mile across the strike to the east, where a 200 ft. band of sandstones dips E. 25° N. at 40°. Eastwards this dip prevails in alternating hard and soft unfossiliferous sandstones but decreases to 32° in the isolated exposures which crop out as low hills in the alluvium of the Mindon *chaung*. There is a fossiliferous band immediately west of Punyo (19° 7′; 95° 4′) village. To the south on Wetto *chaung* the same sequence is met with.

Sequence west of Wutkon.

Shales with intercalated thin sandstone bands underlie the band of hard sandstone immediately below the base of the Irrawaddy gravels west of Wutkon (19° 4′; 95° 7′); they continue to one and a third miles south of Pazeinnein (19° 4′; 95° 6′), where they are underlain by fawn sandstones which dip E. 35° N. at 40°. The dip steepens to 50°, one and a half miles south-west of Pazeinnein. From this point to east of Tantabin (19° 2′; 95° 2′) blue shales prevail.

Up Monda *chaung* from Tantabin, fossiliferous strata are again absent. The Thangyotaung ridge anticline pitches out very suddenly, two and a half miles north by west of Tantabin. To the south, bluish fine-grained sandstones weathering to fawn and containing blue shale intercalations occur. North-westwards up the stream, soft bluish sandstones alternating with slightly harder bands of shaly sandstone, which weathers spheroidally, dip at low angles varying from 10° N. E. to 5° E. 5° N. Towards longitude 95°, horizontal strata occupy the valley west of Thangyotaung and are by a more shaly series around Thanpangyo.

Western flank of Thangyotaung anticline.

Situated one mile west by north of Thangyotaung and one mile N. E. by E. of Thapangyo is the village of Taungyo (not marked on map—19° 6′; 95° 20′) on Taungyo *chaung*. In its vicinity the rocks are horizontal and cultivation is carried out on the residual soil. Eastwards from the village up Taungyo *chaung* a sudden passage from horizontal strata to sandstones dipping 50° W. 30° N. takes place, and marks the line of a strike fault. Further to the east the dip changes to 60° E. 30° N. where a massive band of sandstones forms a steep ridge. This latter consists of 600 ft. of fine-grained bluish sandstones containing numerous cannon ball like concretions loosely set in the main mass.

CHAPTER XI.—DETAILED DESCRIPTIONS OF ROCKS.

IRRAWADDY SYSTEM.

The Irrawaddy System is described by Pascoe[1] as consisting generally 'of a series of loosec lean friable light yellow sand-rock' highly current-bedded and frequently iron stained; it often contains concretions of hard calcareous sandstone, whilst at the base the most typical feature is the number of thin inconstant ferruginous conglomeratic bands.

Physical characteristics.

The iron-staining of the sands most frequently coincides with the current-bedding planes, but may be quite independent of them. The sand consists for the most part of water-worn sub-angular quartz with a little inter-mixed felspar and is a much purer deposit than the typical Pegu sandstone. Mica is frequently a constituent, especially in the higher beds whilst a great deal of ferruginous matter is present mostly in the form of small concretions of limonite or haematite. A common type of such concretions occurring in strings and layers in the sand-rock consists of an external crust of concentric layers of haematite or limonite, spheroidal, ellipsoidal or fantastically irregular in shape enclosing a kernel loose or otherwise of yellow or red ochre or of white clay: the external surface is roughened with adherent sand-particles.

Some of the ferruginous conglomerates, usually the lowest are loose pebbly sands, the pebbles consisting entirely or almost entirely of clay, coated with iron oxide, while others are hard resistant bands from one to six or occasionally ten feet thick in which pebbles of hard stone, especially of milky quartz with or without the clay pebbles, are cemented together in a hard ferruginous matrix. Quartz forms the bulk of the pebbles, but pebbles of sandstone, ochreous mudstone, schist, quartz-veined schist and dark shale also occur. The series is characterised generally by dicotyledonous and more rarely by monocotyledonous fossil-wood which is generally known as "Ingyin Kyauk" from its resemblance to the living Ingyin tree (*Pentacone suavis*). It occurs in the soft-sand rock sometimes as trunks up to 50 feet long and 3 feet in diameter. Where it occurs profusely plinths of pagodas are built of it.'

Age of Irrawaddian system.

The conglomerate horizons occasionally contain the remains of vertebrates and it is from these that the age of the series has been determined. The basal beds are referred by G. E. Pilgrim[2] to the Pikermi stage or Upper Pontian. Cotter[3] sums up the age of the series in the following words:—

'Perhaps too much stress has been laid upon the Pontian and too little upon the Pliocene, age of the Irrawaddy series.......... A collection from the basal beds at Yenangyaung[4] has been shown by Pilgrim to contain a Dhok Pathan (Pikermi).

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[1] *Mem. Geol. Surv. Ind.*, XL, Pt. I, p. 33 *et seq.*, (1912).

[2] *Rec. Geol. Surv. Ind.*, XL, p. 196, (1910).

[3] *Rec. Geol. Surv. Ind.*, LIV, p. 115, (1922).

[4] *Mem. Geol. Surv. Ind.*, XL, Pt. 1, p. 65, (1912).

or *Upper* Pontian fauna. The higher horizons of the Irrawaddies at Yenangyaung are sparsely fossiliferous, and the presence of *Stegodon clifti* recorded by Pilgrim, and of *Rhinoceros* sp. ?=*sivalensis* by Pascoe may perhaps indicate a Tatrot horizon (Lower Pliocene) for the higher horizons. The fauna found by myself near Chaingzauk in the Pakokku district[1] is undoubtedly Tatrot in age and indicates the Lower Pliocene. Further vertebrate evidence is wanting; the genera *Dorcatherium, Telmatodon, Cadurcotherium,* recorded from Burma by Pilgrim all come from the Pegu series. The fossil *Unionidae* from the basal Irrawaddy beds in Thayetmyo district described by E. Vredenburg and B. Pershad[2] are closely related to living species, while the single *Melaniid* found (*Acrostoma variabile*) is still living. Although the evidence is meagre, such as there is favours the view that the bulk of the Irrawaddy series is Pliocene.'

Irrawaddy sandstones Sheet 84-L/7.

In the north of Sheet 84-L/7, the Irrawaddy sandstones consist of fawn-coloured false-bedded sandstones which, in their lower horizons, are banded with thin ferruginous conglomerates, the detritus of which caps the small hills of the flat though broken type of country of the area. Slight eastern dips prevail and a quarter of a mile east of Sinlu (20° 26′; 94° 27′) along the Salin (20° 35′; 94° 40′) road, where the road cuts through a low steeply scarped ridge, a white sandstone band similar to the white bed in the Upper Pegu rocks of the Singu anticline, though not so well defined in its limits, dips 28° east, the average dip of the series east of Sinlu.

The main ferruginous basal conglomerates of the series form a high scarp rising to a height of 1,100 feet about three miles south by west of Sinlu, but gradually become lower northwards where variations in thickness occur and the several members composing the band become more evident. Basal conglomeratic zone is probably the most suitable name for this scarp-forming series in this area.

A similar basal series is found south of Mezali (20° 18′; 94° 30′) in the Tanbotaung (Pt. 1412) hill range which, Cotter, in a progress report, describes as alternate beds of sandstone and reddish conglomerates in which conglomerates prevail. According to Cotter, from the base of the series upwards to at least 4,000 feet, rocks of this type occur and the conglomerate, being soft, easily weathers into a red pebble and silty deposit. The base of the Irrawaddi series is hereabouts characterised by large trunks of silicified fossil-wood, but in the upper beds to the east fossil-wood appears to be rare. In these upper beds, the Irrawaddy series are silty sand and clay, resembling the description given by Theobald[1] although occasional bands of conglomerate do occur. Red earth covers the Irrawaddi series in many places and becomes general, completely concealing the underlying rocks, along the eastern boundary. It grades insensibly into low alluvium and on the lower levels has probably been redeposited. It frequently contains kankar, the best occurrence being in the low-lying area about two miles west of Kalahaung village (20° 18′; 94° 42′).

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[1] *Rec. Geol. Surv. Ind.*, XLV, p. 126, (1915).

[2] *Rec. Geol. Surv. Ind.*, LI, p. 371, (1920-21).

Series in Sheet 112.

In Sheet 112 to the south, the gravelly nature of the beds in the region of the western boundary of the Irrawaddy syncline and of their more sandy occurrence to the east, are mentioned in Cotter's progress report for 1909-10, as also is the manner in which alluvial deposits obscure the Pegu-Irrawaddian boundary in the extreme south-east corner of the sheet on the flanks of the Minbu anticline, where the boundary is marked by a ferruginous conglomerate underlain by a horizon containing selenite. Selenite was also noted by Dr. Cotter in the Irrawaddian series south-south-west of Yethaya (20° 4′; 95° 0′) and west of Pt. 309.

Series in Sheet 113.

In Sheet 113 the Irrawaddian rocks occupy the syncline formed by the western Pegu outcrops and the Minbu and Tagaing anticlines. On the west between the deserted village of Kayugan (19° 57′; 94° 45′) and Kyunbya (19° 56′; 94° 48′) the Pegu-Irrawaddian boundary is, according to Sethu Rama Rau, demarcated by a quartzose pebbly conglomerate with a ferruginous cement. In this area conglomerates are abundant, shales and sandstones are poorly developed, and siliceous fossil-wood occurs only sparsely. Bands containing vertebrate remains are absent whilst pebbles in the conglomerates attain three inches in diameter.

At Mile 55 on the Yenaman (19° 47′; 94° 57′)—Taungu road (19° 54′; 94° 58′), the boundary conglomerates dip north-east at about 20°; at Mile 61 the series are practically horizontal, whilst in Shwedaw *chaung* west of Mile 65 on the same road, they dip 25° west.

The basal beds of the Irrawaddy series forming the western flank of the Tagaing anticline dip steeply at from 60°-70°. The Pegu-Irrawaddian boundary south of the Tazat (19° 59′; 94° 59′)

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[1] *Mem. Geol. Surv. Ind.*, Vol. X, p. 266, (1873).

chaung and on the eastern side of the Tagaing anticline has been affected by the faulting and minor folding which separates the latter anticline from that of the Minbu one to the north.

Series in Sheet 114.

The base of the Irrawaddy series on the west, which further north is characterised by thick ferruginous conglomerates forming a high and prominent ridge, becomes more gravelly to the south in Sheet 114 and is represented by a string of low gravel-covered hills. In the Linke (19° 42′ : 94° 59′)—Bwegyi (19° 36′ : 94° 59′) basin, the limits are not at all clearly defined in the north. Conglomerates are only seen in Linke *chaung* in the north, and west of Bwegyi in the south. In both these places they occur as false-bedded coarse conglomerates and as lenticular stringers in fawn to reddish sandstones. They are generally underlain by a sandy series of Upper Pegus, but south-west of Kyunbya (19° 57′ : 94° 49′) an exception occurs where shales underlie the boundary.

'Wash-out' in basal Irrawaddies.

At the Pegu-Irrawaddy boundary three quarters of a mile east of Mindegale (19° 44′ : 94° 54′) a local unconformity of the nature of a 'wash-out' is visible. The basal Irrawaddies here are represented by red earth with included conglomerates, which are fairly soft, slightly ferruginous and decompose very readily to gravel, so that from here southwards, except where fairly large *nalas* cross, the boundary is only seen as a broken line of scarps, scattered by innumerable quartz and quartz breccia pebbles, the soil having the typical red ferruginous colour of the junction series.

Series in Sheet 159.

In Sheet 159 Bion's mapping as published by Cotter[1] was continued. In marching from Thayetmyo (19° 20′ : 95° 14′) to Tawgyaung (19° 26′ : 95° 9′), I did not find Bion's Irrawaddy boundary, which runs from one mile south by west of Talabasan in the direction of Padaukpin village, showed any evidence of faulting either at Mile 9·2 on the Tawmun (19° 26′ : 95° 9′) road or on the Pun *chaung* north of Kunnon (19° 25′ : 95° 10′).

A small transverse fault was noted just over a mile south of Tawgyaung on the Tawmun road, followed by a bigger and parallel one running west by south along the stream, where the road crosses at Shwedaw Pagoda. Both these faults strike W. 30° S. and down-throw to the south and are probably responsible for the easterly trend of the Irrawaddy boundary to the west. North of the faults, the Irrawaddy boundary encloses the villages in the basin of the Tazi *chaung* and extends northwards to half a mile north of Thayetkyin (19° 28′: 95° 7′) but does not enclose the village of Thayetmyin (19° 28′: 95° 6′), which lies on uppermost Pegu strata. One mile west of Tawgyaung the Irrawaddian strata are composed of fine yellow, white and red sands.

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[1] *Rec. Geol. Surv. Ind.*, LIV, pp. 103-116, (1922).

Irrawaddian outcrops to the south in Sheet 159, consist of a big syncline with a subsidiary one on its south-west flank. The formation consists chiefly of gravels sometimes ferruginous and always false-bedded where seen in cliff sections. They have been described by Theobald[1] as a belt of low hills much scored by ravines and made up of fossil wood beds.

Southerly syncline south-west of Twinle.

In the subsidiary syncline one mile west of Pt. 599 typical fawn Irrawaddy sands are seen and again half a mile east by north of Pt. 543 on the Twinle (19° 18′: 95° 3′)—Legu road (19° 17′: 95° 0′). The fault mentioned in the descriptions of Pegu rocks as being on Daungbyan *chaung* to the north (p. 223) appears to continue southwards down the valley of the Pani *chaung*, as on the east of the river alluvium, only gravel hills are seen, whilst on the west bank opposite Taungbogyi (19° 18′: 95° 3′) alternates of sandstones and shale of the Pegu system, dip south-east at low angles.

The latter are overlain by gravels of the western Irrawaddy syncline; westwards along the boundary, the dip steepens and merges into a fault. This fault continues into Sheet 115 and crosses Kokkozan (19° 19′: 94° 59′) *chaung* immediately south of the village of that name.

A parallel fault cuts across the extreme south-west corner of the sheet and forms for a short distance the southern boundary of the same syncline. The western boundary runs west of the 546-581 ridge along a high scarp underlain by Pegu strata, the nature of which cannot be clearly made out owing to gravel detritus, but as *taungya* cultivation is carried on, it is probably of a shaly nature. It is underlain by an alternating sequence in which sandstones predominate.

The main Irrawaddy sandstone outlier to the east ends in a northerly direction half a mile south of Taungmyin (19° 22′: 95° 2′), where hori-

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[1] *Mem. Geol. Surv. Ind.*, X, pp. 248, 281, (1873).

Main Irrawaddian Syncline.

zontal conglomerate is seen underlain by fawn sandstones. From here the eastern boundary crosses the Thayetmyo-Kyaukkyi road at Mile 13·4 and then meanders along the high ground, west and north-west of Tanlebin, overlying horizontal upper Pegu Sandstones for the most part, although south of Nathe Dâk Bungalow (19° 21′ : 95° 7′) conglomerates were seen overlying definitely shaly strata. The boundary then crosses Minde *chaung* at the stream junction one and a half miles west of Minde, and after forming an arc around a small but well accentuated anticline one and a quarter miles S. 10° E. of Minde, ends up close to the Lime Hill fault.

The northern part is underlain by fawn sandstones at Mile 13-2 on the Mindon Road. Eastwards these sandstones develop thin (1 mm.) laminations of clay and in places they grade into clays with thin micaceous sandy laminae. At Mile 12-2 gravels lie on red earth and are probably due to overlapping by the uppermost Irrawaddy gravels; at Mile 11 shales predominate. Fawn sandstones occur in Tanlebin and Minde *chaungs* underlying Irrawaddian strata but the strata in the southerly pitching end of the anticline one and a quarter miles south of Minde are shales. Dips in these shales are not reliable.

Series in Sheet 160.

To the south-east, this big exposure of Irrawaddian sands and gravels continues across Sheet 160. There is a general tendency for the formation to be more gravelly and conglomeratic to the south-west than to the north-east, where fawn and white sands are intercalated. The basal conglomeratic beds dip steeply on the flanks of the Pyaye anticline five miles west of Peikthalin, and on the south-western flanks of the northern extension of the Pyalo dome. In this latter area at a point two miles north of Pato they are vertical and strike parallel to the main axis of the fold. High gravel cliffs occur from Subotaung (19° 8′ : 95° 8′) north to the Pyaye anticline and also one and a half miles west of Subotaung. These cliffs can be seen from the river as scars on the distant hills.

South-west of Mindon *chaung*.

South-east of Yamo (19° 12′ : 95° 1′) and south-east of Magyibin (19° 11′ : 95° 3′) the Irrawaddy gravels do not appear to attain any great thickness nor on the Kyundawgon (19° 5′ : 95° 6′) and Wutkon (19° 3′ : 95° 8′) hills on the south side of the Mindon *chaung* where they cap the hills and dip north-east under the valley alluvium.

A quarter of a mile north by west of Kama, (19° 1′ : 95° 9′) faulting seems to have let down a small wedge of Irrawaddies among fawn Upper Pegu sandstones.

From Ton (19° 13′ : 95° 5′) along the Peikthalin (19° 15′ : 95° 13′) road Irrawaddian conglomerates, dipping west at low angles occur in a 20-feet cliff section in the stream three miles north-east of Ton. The included quartzose pebbles range up to 6″ in diameter but are generally about 1″; the conglomerates are false bedded, locally unconformable and contain highly ferruginous patches. Specific dips in them mean nothing and where dips have been registered in the map, they have been judged from the general appearance of a cliff section. Three miles north-east by east of Ton the conglomerates have a westerly dip and contain silicified fossil wood. To the west the dip apparently changes to a low easterly one. North from Ton up the Pani *chaung* all exposures of conglomerates are practically horizontal.

West of Paukuga (19° 15′ : 95° 4′) Irrawaddy gravels and conglomerates form the high ground on the Ponna-Milaung Road at the northern extremity of the sheet; they are bounded on the south by the Paukuga fault and are succeeded to the north-east in Sheet 159 first by sandstones and then by horizontal shales.

South of Subotaung, gravels tongue up the spurs from the south-east; to the north soft fawn sandstones are intercalated in them.

North-east of Mindon *chaung*.

North-west of Shasibo (19° 7′ : 95° 0′) pisolites of iron-ore are common, and one and a half miles north-east by north of Inbettaw (19° 6′ : 95° 7′), gravels occur in a cliff section in the *chaung* lying unconformably on soft fawn laminated and false-bedded Pegu sandstones. Fawn laminated Irrawaddy sands dipping 30° south-west are intercalated in these gravels, whilst two miles north of Inbettaw, cliffs of false-bedded gravels attain heights of from 50-100 ft., and contain ferruginous lenticles and lenticles of blue gravels.

The cliff on the Irrawaddy below Kanni (19° 13′ : 95° 12′) consists of fawn Irrawaddy sands with intercalated ferruginous gravels, whilst in the hills to the north-west soft fawn Irrawaddy sandstones pass westwards into gravels. Between Peikthalin and Kanni gravel covered hills and fawn sandstones occur.

CHAPTER XII.—ECONOMIC GEOLOGY.

Petroleum.

In Burma the general conditions governing the formation and accumulation of mineral oil are those provided by a rapidly alternating series of sandstones and shales of shallow water marine type. These conditions obtain in the central anticlinical oil-fields of Burma, namely those of Yenangyat, Singu and Yenangyaung, which are situated slightly to the east of the axis of the Yenangyaung synclinal basin. According to Lepper[1] closed structures which do not have direct access to this syncline have proved to contain little or no oil, and Lepper concludes from this that most of the oil of the main oil-fields has migrated into them from the shaly sediments of the median syncline. From this Lepper develops a thesis that the essential condition for the occurrence of oil-fields in Burma seems to be the preservation and formation of closed structures on the margins of extensive depressed shale areas in the general basin of deposition. This opinion one might add is based on the actual drilling experience and detailed geological work of the Burma Oil Company. As will be apparent, rapidly alternating sandstone and shale strata of shallow marine type are most likely to occur on the margins of depressed areas.

In the western outcrops of Upper Eocene and Pegu rocks of Minbu and Thayetmyo, and in the Pegu rocks of Western Thayetmyo, oil and gas seepages are common, but so far attempts at exploitation have met with little success, and as in the area to the north described by Cotter, little remains to be recorded since the publication in 1912 of Sir Edwin Pascoe's memoir on the oil-fields of Burma. The area has been thoroughly searched, but a brief record of the attempts for production that have been made is not out of place.

Kyetyobin (19° 23' : 94° 23').—Oil seepages occur west of the Shashibo *nala* in the Minbu district, and in 1921-22 a bore was sunk into the sandy series of Pegu rocks which occurs above the Padaung clays at Kyetyobin, north of the Mon river, by the Union Oil Company, Ltd. The rocks form a normal monoclinal sequence of alternating sandstones and shales dipping east at from 30°-35° and no anticlinal or terrace structure is apparent in them. The venture was abandoned when the bore had reached 1,600 feet without meeting with success. It was probably occasioned by the occurrence of oil seepages, and the success which shallow wells were obtaining at the time on a similar monoclinal structure at Yenaman to the south.

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[1] World Petroleum Congress, London, Proceedings, Vol. 1, p. 20, (1933).

Yenaman (19° 47′ : 94° 48′).—South of the Man river numerous seepages occur in rocks both immediately above and below the Pegu-Eocene boundary. Both these seepage zones persist to the south and it is the upper of these which has and is being exploited at the present time at Yenaman.

The structure of this area has been variously interpreted. Murray Stuart[1] interprets it as an anticlinal structure concealed below an overthrust. Stamp[2] interprets it as a pocket of oil-bearing sands situated in the midst of a group of laminated sands and clays forming a homocline (or monocline) with a steady easterly dip of 20° to 25°.

West of Yenaman is a thick series of fawn to bluish sandstones with shale intercalations which dip north-east at from 30°-35°. The sandstones are false-bedded and locally unconformable. The oil is contained in the sandstone series which becomes more shaly both northwards and southwards along the strike. Westwards on the Pegu-Eocene boundary a normal conformable sequence dips north-east at 40°; further to the west the main range forms a faulted anticline of Eocene rocks, and mud volcanoes and gas pools occur along the fault on the western flank of the anticline at Yegubwet and to the south. So far as the evidence goes, Murray Stuart's interpretation is purely hypothetical, and the probable solution is that mentioned by Stamp, namely, the sealing up of local lenses of oil sand by clays. Lepper[3] mentions that dip faults cross the Yenaman monoclinal structure close to the oil-fields.

The productive area forms a narrow triangle having its base about 350-400 yards long on the west, parallel with the Pegu-Eocene boundary, and tapering to the east to its apex 1,100 yards distant. In all 80 wells have been drilled in three areas since 1920 by the Indo-Burma Oil Company (1920), Ltd. In the western area the oil sands vary from a depth of 360 feet in the west to 910 feet, 400 yards to the east-north-east, the zone between 500-700 feet being the most productive; to the north water occurs with the oil. During the first three years of exploitation gas was encountered in the oil sands in this area but the only occurrence of importance was at 810 feet in well No. 50. The eastern area which fills in the acute apex of the triangle contains oil sands between 800 and 1,300 feet. In most of these gas occurs; one well obtained oil at 490 feet. The median southern area obtained oil and gas at horizons between 1,000 and 1,300 feet, although here again an exception occurred where oil was obtained in one well at 353 feet. The logs of the wells seem to show and the occurrence of gas to prove the sealing up of small oil-sand lenticles by shale in the easterly dipping monocline of Lower Pegu strata. Test wells to the north and south have failed to prove the extension of this small and declining field.

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[1] *Journ. Inst. Petr. Tech.*, Vol. XI, p. 484 (fig. 2), (1925).
[2] *Journ. Inst. Petr. Tech.*, Vol. XV, p. 326, (1929).
[3] *Loc. cit.*, p. 20, (1933).

Padaukpin (*19° 22′ : 95° 7′*).—One of the latest accounts of this field together with a map and section of the anticline made by Mr. T. R. H. Garrett for the Premier Oil Company is given by Stamp.[1] The various tests that have been made to develop the field, first by the Burma Oil Company in 1905-08, and in more recent times by the Indo-Burma Oil-fields (1920), Ltd., are mentioned. Further details of the area are also given by Barber.[2]

In all 30 wells have been drilled on this anticline by the Indo-Burma Oilfields (1920), Ltd., since 1920; of these 14 are shallow and tap the oil-sand which has in the past been exploited by hand-dug wells. In the deepest of these wells, No. 21 (428′), oil sands were encountered at 38′-39′, 46′-60′, 78′-89′, 124′-192′, 250′-277′, 396′-420′. Of the 'deep' wells the oil, gas and water sands logged in No. 11 well which was sunk to 1,886′ are given below as being typical:—

No. 11 well.	Oil Sands.	Gas Sands.	Water Sands.
1886	20—40	..	..
	110—120	110—120	..
	200	..	..
	850—860	850—860	860—880
	1070—1075	1070—1075	1040
	1400	1315—1320	1075—1080
	1418—1435	1418—1435	..
	1770	1770	1776
	1815	..	1886

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[1] *Loc. cit.*, p. 327, (1929).

[2] *Mem. Geol. Surv. Ind.*, LXVI, Pt. 1, p. 97, (1935).

Minbu (20° 11' : 94° 53').—The Minbu anticline is described in detail by Pascoe[1] who gives a 4 inch=1 mile map (Plate 38) covering the important and only parts of it which have proved productive. According to Pascoe the structure is that of an acute anticline slightly overfolded towards the east. The beds on the west very often dip as steeply as those on the east, but the asymmetry of the anticline is due more to irregularities in shape than to the greater steepness of the eastern limb over the western. These irregularities suggested to Pascoe intermittency of the folding movement; they are of considerable interest and can be followed fairly easily in the field. The flexure is sharp and deeply denuded; it is not unlike that of Yenangyat but has reached a more advanced stage.

Lepper[2] mentions that of the several pools which occur on this structure the field near Minbu town, and the Palanyon and Yethaya areas further south are the most important.

The Minbu or Shwelinban area occurs on the north side of the fault which runs north-north-east and oblique to the main Minbu anticline immediately to the west of Minbu town. It is along this fault that the mud volcanoes and gas pools shown in Plates 40-43 of Pascoe's memoir occur. North-west of this fault the dips of the strata are more gentle than in the main anticline to the south and the whole structure pitches to the north first at from 12° to 15° and then at 6° to the north of Minbu town in Blocks 2S, 2N and 19P where the crest of the fold is duplicated. In these blocks the concentration of oil is apparently due to the terrace so formed in Miocene strata. In all about 270 wells have been drilled and draw their oil mainly from depths of 450 and 750 feet although sands are common between 100 and 1,000 feet.

Three wells drilled by the British Burma Petroleum Company on the same contour in Block 19P appear to show that the sands are lenticular. Early wells of this company came in at about 25 barrels a day, but dropped to between one and five barrels within six months; one well flowed for a month. Recently the report of a flow from another shallow well in this area lends additional evidence for the view that the oil sands occur as small lenses.

According to Barber[3] one well was drilled to 2,200 feet in this area without obtaining oil in profitable quantities, and none has yet been won from below the shallow zone. Between 1926 and 1929 an attempt at drilling a deep well with rotary equipment near the northern boundary of Block 2S had to be abandoned at 1224 feet owing to the heaving of the formation. No gas sands have been penetrated in this area and the oil produced from the shallow sands is almost free from gas.

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[1] *Mem. Geol. Surv. Ind.*, XL, Pt. 1, p. 158, (1912).

[2] *Loc. cit.*, p. 19; (1933).

[3] *Loc. cit.*, p. 62, (1935).

Htaukshabin Field (*19° 9′ : 94° 53′*). (Block 6S, Minbu anticline).—A few shallow wells have been drilled by the Burma Oil Company in this area in Miocene strata. The area is generally included with that of Shwelinban to the north as the Minbu field.

The Palanyon Field (*Blocks 11S and 13S*) (*20° 6′ : 95° 54′*).—This field lies on a crest maximum or local dome on the main Minbu anticline south of Minbu in strata of Oligocene age. According to Barber[1] good sections of the strata are afforded by the stream which crosses the northern portions of Blocks 13S and 14S where the folding is acute and asymmetrical. The steeply dipping beds of the eastern limb are truncated by a strike fault hading to the east; east of the fault the beds exposed at the surface are slightly inverted. The field was located and is worked by the Burma Oil Company Ltd. Early wells situated near the crest of the structure passed through the axial plane into the steeply dipping beds of the eastern limb without obtaining oil. Since 1912 over 20 wells have been drilled in this area and produce from sands at depths of approximately 900, 1,400, 1,600 and 2,300 feet. Details of the gas sands which were met with in drilling between 1,000 and 2,400 feet are given by Barber.[2] The most productive gas sand was found in Well No. 26 at a depth of 2,261 feet; it gave an estimated yield of 1,800,000 cubic feet per day.

The Yethaya Field (Minbu anticline 20° 5′ : 94° 57′).—The small Yethaya field is, according to Lepper[3], situated on a local dome in Block FS. close to and east of the main axis of the Minbu anticline, which runs through Blocks 15S and AS to the west. According to Barber[4] the dome is asymmetrical but the axial plane hades slightly to the east in contrast to that of the main structure. The same authority states that in 1912 the only sands which were exploited in the field were the shallow sands of Block 18S to the north, the most important of which were at depths of 300 and 600 feet. Since that time over 50 wells have been drilled by the Burma Oil Company in Block FS and in addition to the 600-foot sand, productive sands have been exploited at depths of approximately 900, 1,400, 1,500, 1,700, and 1,900 feet whilst further oil-sands have been recorded at depths of 2,100, 2,800, 3,800 and 4,100.

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[1] *Mem. Geol. Surv. Ind.*, LXVI, Pt. 1, p. 65, (1935).

[2] *ibid.*, p. 66.

[3] *Loc. cit.*, p. 19, (1933).

[4] *ibid.*, p. 67.

The oil-sands in this field are rich in gas and pockets of free gas have been of frequent occurrence states Barber[1] in giving details of the gas occurrences in both this area and in Block AS. to the west where gas was encountered in a well of the Irrawaddy Petroleum Syndicate on the southerly pitching end of the Palanyon dome.

During 1911-13 the British Burma Petroleum Company Ltd., drilled fourteen wells to depths of 700′-1,009′ in Block 18S. The wells gave an initial production of 100 barrels a day. More recently, in 1924, a well was drilled by the same Company to 1,060 feet, met with no success and was abandoned. The surface rocks exposed in the small subsidiary Yethaya dome are of Miocene age.

All the four fields mentioned above on the Minbu anticline have now practically completed all drilling of economic value for locally proved sands and are mainly producing fields, the results from deeper drilling having not been encouraging.

Sakangyi (*19° 23′ : 95° 7′*).—Just north of the main Thayetmyo-Mindon road between Miles 5 and 6, four wells were drilled in 1924-25 by the British Burma Petroleum Company on a small terrace on the nose of the northerly pitching anticline of Upper Pegu rocks which occurs between the Thayetmyo and Tawmun exposures of Irrawaddian gravels and sands. The first well came in at about 100 barrels a day from a depth of from 545-550 feet but dropped at once to 25 barrels a day and very soon after to ten barrels. Subsequent wells sunk were all failures; the first reached a depth of 2,480 feet and had a show of oil from 565 to 595 feet; the second was abandoned at 700 feet and the third at 2,700 feet.

Banbyin (*19° 25′ : 95° 2′*).—Banbyin is mentioned by Pascoe[2] who notes it as on the north-westerly continuation of the Padaukpin anticline. According to Barber[3] between the years 1904 and 1906 four wells were drilled by the Burma Oil Company near the village of Banbyin. A little oil and gas associated with salt-water was encountered in Well No. 1 at a depth of 800 feet and a little oil and gas at a depth of 140 feet in No. 2. No occurrences of gas were recorded in the logs of the other two wells.

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[1] *Mem. Geol. Surv. Ind.*, LXVI, Pt. 1, p. 67, (1935).

[2] *Loc. cit.*, p. 171, *et. seq.* (1912).

[3] *Mem. Geol. Surv. Ind.*, LXVI, Pt. 1, p. 98, (1935).

The crest of the broken anticline of Banbyin passes across the stream bed about half a mile west of Banbyin village and on the north side of the stream a horizontal sandstone from which oil seeps is overlain by shale. Hand-dug wells have been sunk into this sandstone intermittently from time immemorial and in 1930 further attempts were made when eight hand-dug wells were put down, the deepest to a depth of 60 feet. Oil and gas were found in every hole between 31 and 45 feet, one barrel per week being the best production obtained from an individual well.

Tagaing (19° 56′ : 94° 58′).—The small and short lived oil-field of Tagaing was developed on the north pitching nose of one of the most northerly of the anticlines which occur in the big exposure of Pegu rocks west of the Irrawaddy in Sheet 158. To the south this structure is steeply folded and faulted and low beds of the Pegu System are exposed in it. According to Stamp,[1] who gives a sketch map of the northerly end of the structure, the oil was apparently held up by a 'terrace' caused by a change of pitch. Barber[2] states that between 1914 and 1922, six wells were drilled near Tagaing in Blocks 6, 7, 10, 11, 14 and 15 of the area officially known as the Minhla oil-field. In 1919 the Burma Oil Company became interested in the area and details of the oil and gas sands met with between 200 feet and 2,545 feet in the various wells are given by Barber from information supplied by that company. The field commenced with a production of nearly 23,000 gallons in 1914, reached its maximum of nearly 114,000 gallons in 1919, dwindled to just over 66,000 gallons in 1921 and thence was no more.

The Mindegyi (19° 48′ : 94° 56′)—Kyawdo (19° 45′ : 95° 0′)—Yinaing uplift (19° 40′ : 95° 2′).—This structure lies en èchelon, to the south-west of the Tagaing anticline, and about eight miles east of the Yenaman field; its northern end is separated from the two areas named by bays of Irrawaddian strata and successively lower Miocene and Oligocene strata are met with from the north southwards along this symmetrical fold. According to Stamp[3] a deep test well was commenced in 1911 by the Burma Oil Company at Kyawdo and taken to a depth of 3,628 feet, faint shows of oil being struck at 1,463, 1,637 and about 2,300 feet, and a show at 2,627 feet which was regarded as 'good for two or three barrels'. Barber[1] reports of the same wells that small shows of gas were encountered between 861 and 867 feet, at 2,658 feet, and at 3,410 feet. The Yinaing area was tested by the Burma Oil Company by two holes in 1911-12. These reached 900 and 600 feet and no oil shows were obtained. Lepper[2] reports that no commercial success attended the efforts of the Burma Oil Company in the drilling of several wells on this structure. Three wells were drilled by the Indo-Burma Oil-fields (1,920) Ltd., near Mindegyi (19° 48′ : 94° 58′) to depths of 1075, 950 and 800 feet respectively. Shows of gas were encountered in the first and second wells; no oil production was obtained.

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[1] *Inst. Pet. Tech.*, XV, p. 339, (1929).

[2] *Loc. cit.* p. 101, (1935).

[3] *Loc. cit.*, p. 339, (1929).

Monatkon (19° 32 : 95° 1′)—Okpon (19° 28′ : 95° 1′).—About 20 miles north-west of Thayetmyo and immediately to the east of the syncline bordering the western outcrops the Monatkon-Okpon structure has been tested by the drill, so far without success, in an attempt to find oil below the thick Oligocene clays which occupy the cores of the two structures.

Monatkon.—About 1912-13 the Burma Oil Company drilled a hole on the Monatkon structure to 1,550 feet. A second hole was taken to 1,240 feet and then to over 3,000 feet but without success. At the present time (December, 1936) the same Company is still continuing with a bore which has reached almost 8,000 feet. So far no economic success has been attained and the bore must by now be well down into Eocene strata.

Okpon.—About 1922-23 the Indo-Burma Oil-fields (1920) Ltd., drilled a well to about 2,000 feet on this structure but met with no success. According to Barber[3] two further wells were drilled in 1925 and 1926 by the same Company. In the first well, which was taken to a depth of 3,000 feet, no gas was encountered, but in the second well gas was found at a depth of 1,135 feet.

Pyaye (19° 12′ : 25° 10′).—This structure is formed of a small exposure of rocks of the uppermost Pegu series of just over two square miles in area and occurs in the midst of the main exposure of Irrawaddian rocks south-west of Thayetmyo and eight miles distant from that town. It was mapped originally about 1912 by Murray Stuart who at that time regarded the upper-most Pegu rocks as marine Irrawaddies. Later it was examined by Stamp for the Indo-Burma Petroleum Company. Although there was no written record of the existence of this structure it was shown on the 1″=1 mile map of that area which was supplied to the general public by the Geological Survey of India.

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[1] *Mem. Geol. Surv. Ind.*, LXVI, Pt. 1, p. 100, (1935).

[2] *Loc. cit.*, p. 20, (1933).

[3] *Loc. cit.*, p. 99, (1935).

Stamp[1] describes the area in the following words :—

> " It is a beautiful little open dome with dips on all sides. The area of Peguan exposed is about two and half miles long and the greatest breadth rather over a mile. Only a thin skin of the exposed Peguan rocks has been removed and the Peguan exposure forms a marked ridge. From this ridge there is a beautifully developed radial drainage, whilst the lowest beds of the Irrawaddian sands form an inward facing escarpment through which the streams break by picturesque little gorges. The writer studied the ground in detail in the height of the hot season—in April 1924—when the nearest water had to be brought in buckets for a distance of over three miles, and when every tree in the ' indaing ' forest and scrub was leafless. But the view from the Peguan ridge, with the silver Irrawaddy shimmering in the far distance, was sufficient compensation for a thermometer which wandered up to 110° every afternoon. In spite of the numerous failures in the Thayetmyo district, it seemed that the Pyayo dome was exceptionally promising. In the first place, the structure was ideal, in the second place the gathering ground of about 40 square miles was exceptionally good ; in the third place there was a good chance of shallow oil in the upper sandy beds of the Peguan as well as at lower horizons corresponding with the Padaukpin horizon :..............the I. B. P. put down a test and got a small show of oil at the upper horizon, then passed through a great thickness of shale, to strike a tremendous gas sand ".

This gas sand was struck in Well No. 1 on the 13th July 1926 at a depth of 2.525 feet and the yield of gas was found to be 39,000,000 cubic feet ; on the 20th August the yield of gas was again measured and found to be 30,668,000 cubic feet. The well was closed down by order of the Government of Burma, but meanwhile over 30,000,000 cubic feet of gas per day were lost over a period of eight months. Further details of the wells sunk, the gas sands encountered and the operations by which Well No. 1 was eventually brought under control are given by Barber[2] who regards 30,000 million cubic feet as a conservative estimate of the volume of gas remaining in the known gas sands of the Pyaye field.

Although no oil in economic quantity has been as yet obtained from the Pyaye dome, the deepest well has only penetrated to a depth of 2,525 feet. The area cannot therefore be said to have been thoroughly tested and as the conditions for the accumulation and concentration of oil are of such exceptional favour, it will be very remarkable if the company holding the area do not sink a deep test as soon as the more pressing needs of drilling in competitive areas abates.

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[1] *Loc. cit.*, LXVI, Pt. 1, p. 336, (1929).
[2] *Loc. cit.*, pp. 89-97, (1935).

In 1935 the Burma Cement Company was floated by Messrs. Steels Ltd., Rangoon, the agents of the Indo-Burma Petroleum Company, to utilise the Oligocene limestone which occurs on the Lime Hill (Myinmagitaung) close at hand for the production of cement and the gas of the Pyaye dome as fuel.

It is of interest to note that in 1936 in looking through old maps in the Geological Survey of India files, I found a ¼" to the mile map of Theobald showing the Pyaye structure marked on it. In an accompanying ¼" to the mile map, the geology however is identical with that shown on the ⅛" to the mile map which accompanies Theobald's memoir.[1]

Coal.

Coal or carbonaceous shale was noted in the Eocene rocks of the western outcrops from the northern limit of the area, south to the latitude of Thayetmyo and mention has been made in the text of the majority of the occurrences. Their co-ordinates are given below :—

(1) One and a quarter miles west by south of Myauk-u (20° 29′ : 94° 19′ 30″).
(2) Two miles east by north of Magyisan. (20° 26′ : 94° 19′).
(3) One and a quarter miles N. E. by N. of Kyi-on (20° 23′ : 94° 20′).
(4) One mile south-east of Kyi-on (20° 22′ : 94° 20′).
(5) Two miles east of Pa-aing E. (20° 15′ : 94° 22′).
(6) Immediately south and one mile south-east by south of Peinhnebin, Manchaung. (20° 5′ : 94° 32′).
(7) Kyaukset (20° 2′ : 94° 38′).
(8) One and a half miles north-west of Kyet-u-bok (20° 0′ : 94° 38′).
(9) One and a half miles south by west of Kyet-u-bok (19° 58′ : 94° 40′).
(10) Two and a quarter miles west by south of Magyisan. (19° 56′ : 94° 40′).

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[1] *Mem. Geol. Surv. Ind.*, Vol. X, Pt. 2, (1872).

(11) One mile S. S. W. of Tabingyo. (19° 54′ : 94° 41′).
(12) Two miles west by north of Kanni. (19° 52′ : 94° 37′).
(13) Two miles south by west of Kyaukpon. (19° 48′ : 94° 46′).
(14) One and a quarter miles south by west of Thabyemyaung. (19° 46′ : 94° 48′).
(15) Pani *chaung*, one mile south of Myothit. (19° 44′ : 94° 41′).
(16) One and a half miles south of Gwegyaw (19° 42′ : 94° 51′).
(17) Two miles W. S. W. of Kanywa. (19° 41′ : 94° 53′).
(18) Two and three-quarter miles W. S. W. of Singaing. (19° 40′ : 94° 54′).
(19) One and a quarter miles W. S. W. of Talokyin. (19° 34′ : 94° 56′).
(20) One mile north-west of Mibauk. (19° 27′ : 94° 52′).
(21) One and a half miles south of Pungyi. (19° 25′ : 94° 58′).
(22) Kyaukkala. (19° 27′ : 94° 44′).
(23) In the lowest shales of the Pegu series below the Lepidocyclina limestones of the Lime Hill, five miles south of Thayetmyo (19° 16′ : 95° 11′).

All these coal seams are lenticular and inconsistent in their occurrence. Generally they are associated with shales, occasionally highly contorted, and none of them are of economic importance. Their occurrence has been mentioned owing to the perennial nature of enquiries concerning them.

Steatite.

The steatite mines of the Minbu district were examined by Hayden[1] in 1896. The two chief localities are (1) 30 miles west of the village of Hpa-aing (20° 15′ : 94° 23′) and (2) 12 miles west of Shauktaung (19° 58′ : 94° 28′) in the Ngape township. The steatite occurs in veins in the serpentine so common along the fringe of the Arakan Yoma. These bands have a maximum thickness of 9 inches. The method of working is primitive, a shaft being sunk on the vein and worked until all the steatite is extracted, the shaft following all the ramifications of the primary vein and any subsidiary ones subsequently met. No attempt is made at ventilation and extraction ceases during the rains. No production has been reported for many years. A sample from this locality tested by Mallet[2] was of good quality, pale green in colour, compact, and cut freely.

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[1] *Rec. Geol. Surv. Ind.*, XXIX, Pt. 4, pp. 71-76 (1896).
[2] *Rec. Geol. Surv. Ind.*, XXII, Pt. 2, p. 67, (1889).

Chromite.

Chromite has been reported from the western part of the Thayetmyo district from three miles north-west of Kadaing village (19° 22′ : 94° 39′), where it occurs as segregations in the serpentine intrusion through which the Mindon *chaung* flows. The occurrence is apparently only of academic interest as Theobald[1] in describing the serpentine fails to mention it. Bion in his field note-book for the 1914-15 field-season mentions the occurrence of chromite as a segregation in the same serpentine, but does not amplify the statement further, and one can only conclude that its occurrence was rare.

I made a fairly exhaustive search in the serpentine occurrence three miles west of Gyobin (19° 3′ : 94° 52′), 35 miles to the south-east, but failed to find any chromite either *in situ* or as boulders in the stream bed which cuts through the serpentine.

The area north-west of Kadaing has been held under prospecting license for chromite at various periods but never more than laboratory samples have been produced from it.

Limestone.

The foraminiferal limestones of Oligocene and Eocene age noted in the descriptive pages are suitable for the manufacture of cement. In general the situations of the main outcrops are at present rather remote, but owing to the proximity of the Pyaye gas-field which can be utilised as a fuel for the kilns, and the Irrawaddy river for transportation, the examination of the possibilities of the *Lepidocyclina* limestone of the Lime Hill (Myinmagyitaung) was taken in hand some years ago by Messrs. Steels Ltd. As a result the Burma Cement Company was floated in 1935 to exploit the limestone of the Lime Hill in conjunction with gas from the Pyaye field. The project is not yet in the production stage but it has as large shareholders the group of companies comprising the Cement Marketing Company of India, Ltd., the Associated Portland Cement Manufactures Ltd., the British Portland Cement Co., Ltd., and the Tunnel Portland Cement Co., Ltd., and appears to be assured of success. That this is the opinion of the general public can be gathered from the fact that the capital was greatly oversubscribed and the Rs. 10 shares now stand at over Rs. 20.

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[1] *Mem. Geol. Surv. Ind.*, X, p. 144, (1870).

APPENDIX I.

SUMMARY OF STAMP AND LORD'S PAPER[1] ON THE ECOLOGY OF PART OF THE RIVERINE TRACT OF BURMA.

"1. *Irrawadian Sands and Gravels.*—In well-drained, *i.e.*, in slightly rolling, country in the south the characteristic vegetation is the *Tectona grandis* forest (Teak Forest). Indeed, in the area under consideration practically all the teak forests are on Irrawaddian and one only finds a few scattered trees on the sandier portions of the Pegu. Teak seems to be limited by an annual rainfall of about 37 inches and is not found far north of Thayetmyo (37·34 inches) and Allanmyo (38·29 inches). Even there all the teak is what is technically known as "stunted" teak—a fully grown tree having a girth of less than five feet at a height of five feet from the ground—and many of the trees have a bole divided almost to the base. From this latitude northwards the Irrawaddian is covered by the *Dipterocarpus-Pentacme* forests (Eng forests or Indaing and Ingyin forests). Typical forest of these types is well seen in the broad syncline about 50 miles north-west of Thayetmyo. North-east of Prome both Teak and Eng forests are found on Irrawaddian rocks—especially the latter. Eng forests seem to thrive on the lightest soils—almost pure sands whilst teak is more frequently found on the more clayey hill-wash from the Irrawaddian. As the rainfall drops below 34 or 35 inches, *Dipterocarpus tuberculatus* (Eng) disappears and then *Pentacme suavis* (Ingyin), and their place is taken by a varied assemblage of trees but particularly by *Diosphyros birmanica* and *Terminalia tomentosa*. Comparatively large and healthy *Acacia catechu* and *Tectona hamiltonii* are numerous and this type of forest may be called the *Diospyros* forest, though in reality it is very mixed. The type may be studied east of Sinbaungwe and, less perfectly, south-west of Minbu, Northwards, *Acacia catechu* and *Tectona hamiltonii* increase in importance and one gets the *Acacia catechu-Tectona hamiltonii* forest (Sha-Dahat forest). Finally, as may be observed near Minlindaung, Yenangyaung, the natural vegetation of the Irrawaddian is a very thin *Acacia catechu* thorn scrub and, locally, the *Euphorbia* thorn scrub or semi-desert.

This general scheme is affected by several important factors.

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[1] L. Dudley Stamp and Leslie Lord.—The Ecology of Part of the Riverine Tract of Burma.—Journal of Ecology (Vol. XI. No. 2, p. 140 *et. seq.* September 1923).

1. In Plateau country and especially where the Irrawaddian is horizontal, the iron salts tend to "pan" and water rapidly runs off. Frequently in the midst of a typical Eng forest one finds level areas covered with *Acacia* thorn forest or even with *Acacia* thorn scrub. This is well seen near Pogyi, east of Sinbaungwe.

2. Tracts of pale plastic interbedded clays may also give rise to poor vegetation. The Eng-Ingyin forests passed into what is practically an Ingyin savannah (well seen north-west of Lehla). On the other hand, there are areas of these clays where the vegetation—especially the undergrowth—is distinctly richer (*see* p. 144).

3. Near stream courses the vegetation tends to be much more varied. This may be noted along the Kyini *chaung* (eastwards from Allanmyo) and also near Kyauksaungsan.

4. The Irrawaddian is often largely obscured by level tracts of alluvium—which are usually cultivated but when left become covered with *Zizyphus* thorn scrub. Cultivated land, when allowed to lie fallow for a few years, develops this type of vegetation.

5. Rolling Irrawaddian country furnishes good ground-nut soil and the natural vegetation is often obscured by cultivation.

"2. *Pegu Sands and Loams*.—It has already been stated that most of the hill-ranges which border the River Irrawaddy are built up of steeply dipping Pegu rocks—hard sandstone bands alternating with soft sandstones or shales. The distribution of vegetation is largely controlled by configuration, but the hills are characteristically covered by a mixed Savannah forest, at least as far north as opposite Sinbaungwe. Bamboo is abundant and a feature frequently to be observed is that the spurs of the hills are covered mainly by bamboo (*Dendrocalamus strictus*) whilst the trees occupy the intervening depressions and gorges.[1] Teak occurs as far north as Kama or even as Thayetmyo but only as scattered trees. It is difficult to name typical trees in this mixed forest (*see* Section V) but *Vitex limonifolia* is very common in the south (*e.g.*, at Kama); further north *Heterophragma adenophyllum* and *Dolichandrone stipulata* are noteworthy (south of Thayetmyo) Ingyin (*Pentacme suavis*) is common as far north as Sinbaungwe. Though not numerically strong *Bombax insigme* is conspicuous owing to its being leafless from nearly November onward. On somewhat lower ground the sandy bands in the Pegu clays may be picked out by the recurrence of the Ingyin or *Diosphros* forests of the Irrawaddian (as near Obogon and Monatkon and Yenangyi). Similarly, the dip-slopes of the thin sandstone bands which occur in the midst of the Pegu clays—as opposite Sinbaungwe—are covered with a low but rich woodland (*Acacia catechu* and *Tectona hamiltonii*) which contrasts strangely with the bare scarp slopes of the clays. From Migyaungye and Minhla northwards the large quantity of gypsum in the clay bands has a deleterious effect and the *Acacia-Tectona* thorn forest prevails. On the Pegu of Minbu this has passed to an *Acacia* thorn scrub or even to the *Euphorbia* semi-desert, though the latter is more characteristic of the Pegu inlier of Yenangyaung.

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[1] Outside the area studied, from 30 miles east of Prome eastwards, the great teak reserves are on highly folded, sandy Pegu rocks. The drainage is good and rainfall probably just over 50 inches.

"3. *Pegu Clays.*—As a whole the stiff, unbedded clays of the Pegu tend to be unfavourable to vegetation though the soils which they yield vary to an extraordinary degree according to the rainfall. In the south the tract of Sitsayan Shales around Sitsayan may be taken as typical. Its vegetation has not been studied in detail but seems to be mainly a Bamboo-*Acacia* savannah forest. In Section V this is treated as a modification of the *Acacia* thorn forest. There is a dense middle story of bamboo and small trees, an undergrowth of long grass, especially in patches and scattered larger trees. The latter includes *Terminalia bialata*, *Acacia catechu* and *Zizyphus jujuba*—all trees characteristic of drier regions on a more open soil. Here as elsewhere, it is to be noted that bamboo has a deleterious effect on small grasses and the ground between the clumps of bamboo is often bare. A similar Bamboo-*Acacia* community occurs on the Pegu clays west of Thayetmyo. Further north-west, over large areas wherever surface drainage is moderately good, a *Tectona hamiltonii*—*Terminalia oliveri* savannah forest is typical of the Pegu clays. Whenever drainage is bad over level stretches of plateau, etc., this gives place to the *Acacia catechu* thorn forest. Where the rainfall drops below about 35 inches the "Kyattimye" type of soil develops and the thorn forest passes to the *Acacia catechu* thorn scrub. The latter type of vegetation covers large areas near the river from Thayetmyo northwards to Minhla. At times there are large bare patches where even the *Acacia catechu* fails to grow, elsewhere the general barrenness is relieved by richer growth near stream courses or in hollows with better drainage where there is a little sand or bands of sandstone in the clays (as opposite Sinbaungwe) or where there is a superficial covering of gravel. North of Minhla all the Pegu clays tend to be sandy (Minbu Anticline) but the more clayey portions carry a thin *Acacia catechu* thorn scrub grading into the *Euphorbia* semi-desert.

"It should be noted here that the line marked on the folding map as the southern limit of the Kyattimye is the limit of the area within which this type of soil is predominant or characteristic; scattered patches do occur further south. The presence of a little lime makes a considerable difference in the vegetation on the Pegu clays. There is only one instance in the district under consideration and that is the Tondaung or Lime-Hill, near Thayetmyo where a band of limestone occurs in the midst of clays and sandy clays. One finds even teak growing fairly commonly on the clay slopes, other trees are varied and bamboo undergrowth isconspicuous.

"4. *Chaung Alluvium and Hill-Wash.*—Much of this land is cultivated but wherever level tracts have been left they are almost invariably covered by *Zizyphus* thorn scrub, varying in richness according to the rainfall; in the south being associated with bamboo, in the north with the wild Castor (*Ricinus communis*) or with *Jatropha* spp. Wherever drainage is better and near chaungs the "hedge-row vegetation" characterised by *Combretum apetalum* is found. Small areas of chaung alluvium naturally carry a vegetation more closely allied to that of the surrounding country.

"5. *Alluvium of the River Irrawaddy.*—Sandbanks, which actually consist for the most part of fine silt, are characteristically covered by the conspicuous "Kaing grass." This land, however, is very fertile and much cultivated. Areas rarely covered during the highwater season soon begin to bear trees. The greater part of the rice-crop of this part of Burma is grown on the extensive tracts of alluvium. Such as between Pyinbyu and Minbu. Seen from a distance these are level areas with large scattered trees. Though scarcely a natural formation, the "Riverside Parkland" may be noted here, since it invariably strikes the eye along the river bank and near villages. Large shady trees—mostly planted—such as *Tamarindus indicus*, the toddy palm (*Borassus flabellifer*) and *Bombax malabaricum*—occur scattered or in groups whilst the intervening ground is either cultivated or covered with a short turf or with a miscellaneous tangle of plants such as characterises waste land in most parts of the world."

APPENDIX II.

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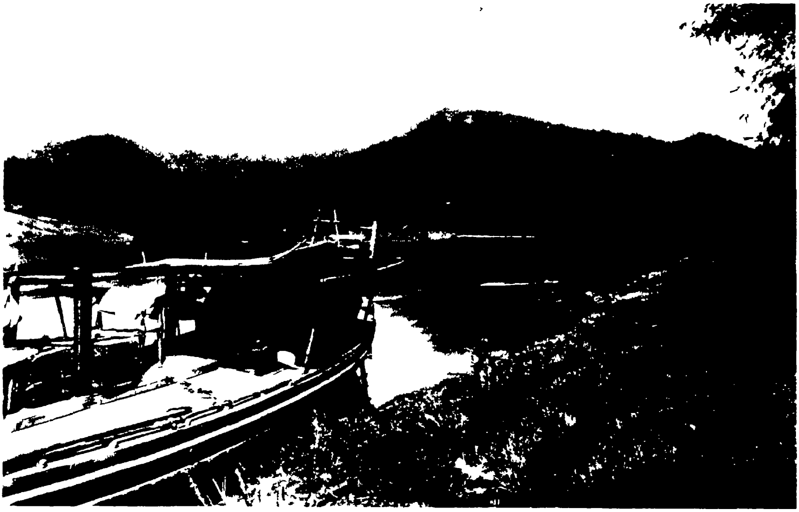


FIG 1 SHWENATTAW PAGODA RIDGE, VIEW TAKEN FROM HALF A MILE S W BY W OF LEYE MU (MINDON, MAHTON) *CHAUNG* THAYETMYO DISTRICT

E. I. G. Clegg, Photos *G. S. I., Calcutta*

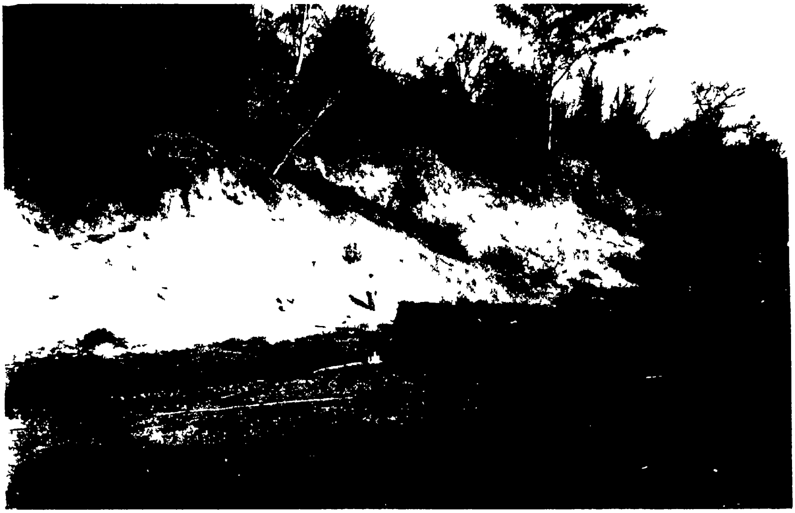
FIG 2. LOW DIPPING STRATA OF THE MIDDLE SANDSTONE DIVISION (OKHMINTAUNG RIDGE SERIES) OF THE PEGU SERIES IN CHINHNIT *CHAUNG* 3 MILE SOUTH-BY-WEST OF CHINHNIT VILLAGE

FIG 1 KAMA FORESHORE NORTH SECTION SHOWING SHALY FOSSILIFEROUS SERIES ON THE NEAR SIDE OF THE WHITE PAGODA FORMING A BAY BETWEEN TWO SANDSTONE BANDS

I I G Cl, Photos

G S I, Calcutta

FIG 2 KAMA FORESHORE SOUTH SECTION SHOWING SANDSTONE BANDS (FOSSILIFEROUS) WITH CALCAREOUS CONCRETIONARY BOULDERS

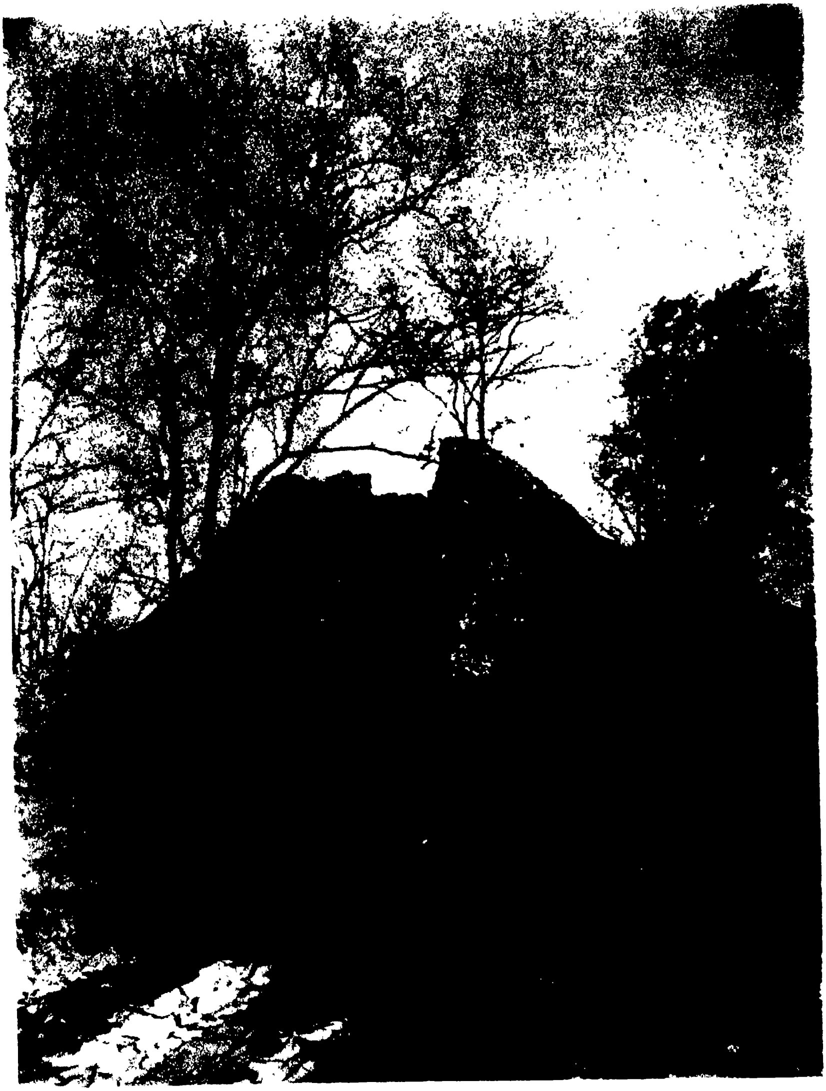


E L G Clegg Photo

FIG 1 SHALE CLIFF IN THE LOWEST DIVISION OF THE PEGU SERIES, MADE *CHAUNG* DUE NORTH OF KYAUKME VILLAGE

S S Rama Rau Photo. *G S I, Calcutta*

FIG 2 WESTERLY ARM OF THE YINAING ANTICLINE SHOWING MINOR FOLDING



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Part 3 (out of print).—Maskat and Massandim on east of Arabia. Example of local jointing. Axial group of Western Prome. Geology of Bombay Presidency.

Part 4 (out of print).—Coal in northern region of Satpura basin. Evidence afforded by raised oyster banks on coasts of India, in estimating amount of elevation indicated thereby. Possible field of coal-measures in Godavari district, Madras Presidency. Lameta or intra-trappean formation of Central India. Petroleum localities in Pegu. Supposed eozoonal limestone of Yellam Bile.

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Part 4 (out of print).—Iron deposits of Chanda (Central Provinces). Barren Islands and Narkondam. Metalliferous resources of British Burma.

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Part 3 (out of print).—Geological observations made on a visit to Chadderkul, Thian Shan range. Former extension of glaciers within Kangra district. Building and ornamental stones of India. Materials for iron manufacture in Raniganj coal-field. Manganese-ore in Wardha coal-field.

Part 4 (out of print).—Auriferous rocks of Dhambal hills, Dharwar district. Antiquity of human race in India. Coal recently discovered in the country of Luni Pathans, south-east corner of Afghanistan. Progress of geological investigation in Godavari district, Madras Presidency. Subsidiary materials for artificial fuel.

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Part 3 (out of print).—Shahpur coal-field, with notice of coal explorations in Narbada regions. Coal recently found near Moflong, Khasia Hills.

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Part 3 (*out of print*).—Fossil floras in India. Geological age of certain groups comprised in Gondwana series of India, and on evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. Relations of fossiliferous strata at Maleri and Kota, near Sironcha, C. P. Fossil mammalian faunæ of India and Burma.

Part 4 (*out of print*).—Fossil floras in India. Osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Plesiosaurus in India. Geology of Pir Panjal and neighbouring districts.

Vol. X, 1877.

Part 1 (*out of print*).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. Estheira in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Embydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (*out of print*).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (*out of print*).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (*out of print*).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis', McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (*out of print*).—Geology of Sind (second notice). Origin of Kumaon lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

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Part 3 (*out of print*).—Geological features of northern Madura, Pudukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia speciosa, Royle (Sphenophyllum trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Nerbudda.

Part 4.—"Attock Slates" and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1 (*out of print*).—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Budiu, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (out of print).—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of North-Eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas'. Mammalian fossils from Perim Island.

Part 2 (out of print).—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain : and Coal and Metalliferous Mines Act of 1872 (England). Cobaltite and danaite from Khetri mines, Rajputana; with remarks on Jaipurite (Syepoorite). Zinc-ore (Smithsonite and Blende) with barytes in Karnul district, Madras. Mud-eruption in island of Cheduba.

Part 3 (out of print).—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4 (out of print).—Unification of geological nomenclature and cartography. Geology of Arvali region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah district, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *viâ* Sach Pass. South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district; (2) arsenical pyrites in same neighbourhood; (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-field. Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3 (out of print).—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal-field, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Gold-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia, Kays (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont Skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosalpore, Jabalpur district. Umaria coal-field.

Part 3 (*out of print*).—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustidens in India. Traverse between Almora and Mussoorree. Cretaceous coal-measures at Borsora in Khasia Hills, near Laour in Sylhet.

Part 4 (*out of print*).—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1 (*out of print*).—Annual report for 1883. Smooth-water anchorages or mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Kurnool district. Geology of Chuari and Sihunta parganas of Chamba. Lyttonia, Waagen, in Kuling series of Kashmir.

Part 2 (*out of print*).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Re-discovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (*out of print*).—Microscopic structure of some Arvali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipore, Central Provinces. Turquoise mines of Nishâpûr, Khorassan. Fiery eruption from Mynbyin mud volcano of Cheduba Island, Arakan. Langrin coal-field, South-West Khasia Hills. Umaria coal-field.

Part 4 (*out of print*).—Geology of part of Gangasulan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takht-i-Suleiman. Smooth-water anchorages of Travancore coast. Auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam caves.

Vol. XVIII, 1885.

Part 1 (*out of print*).—Annual report for 1884. Country between Singareni coal-field and Kistna river. Geological sketch of country between Singareni coal-field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2 (*out of print*).—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussoorre.

Part 3 (*out of print*).—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthalla and Chandpur meteorites. Oil wells and coal in Thayetmyo district, British Burma. Antimony deposits in Maulmein district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (*out of print*).—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1 (*out of print*).—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian coal-bearing beds. Afghan and Persian Field notes. Section from Simla to Wangtu, and petrological character of Ambhibolites and Quartz-Diorites of Sutlej valley.

Part 2 (*out of print*).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruption rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (*out of print*).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (out of print).—Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field-note from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

VOL. XX, 1887.

Part 1 (out of print).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2 (out of print).—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east, with speckled sandstone in west, of Salt-range, in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-field (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

VOL. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stones obtained off Colombo.

Part 2 (out of print).—Award of Woolasten Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

VOL. XXII, 1889

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-fields, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part I.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicyonodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive-group, Salt-range. Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field-notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal fields of Lairungao, Meosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provincial Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

Vol. XXIV, 1891.

Part 1 (out of print).—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2 (out of print).—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-spring near Bawgyo, Thibaw State.

Part 3 (out of print).—Boring in Daltonganj Coal-field, Palamow. Death of Dr. P. Martin Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4 (out of print).—Mammalian Bones from Mongolia. Darjiling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

Vol. XXV, 1892.

Part 1 (out of print).—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dasht-i-Bedalot; with appendices on Chammans of Quetta; and Artesian water-supply of Quetta and Pishin.

Part 2 (out of print).—Geology of Saféd Kôh. Jherria Coal-field.

Part 3 (out of print).—Locality of Indian Tscheffkinite. Geological Sketch of country north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4 (out of print).—Oil Springs at Mogal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Ambar-like Resin in Burma. Triassic Deposits of Salt-range.

Vol. XXVI, 1893.

Part 1 (out of print).—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma, Burmite, new Fossil Resin from Upper Burma. Prospecting Operations, Mergui District, 1891-92.

Part 2 (out of print).—Earthquake in Baluchistan of 20th December 1892. Burmite, new amber-like fossils from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3 (out of print).—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim. Boring at Chandernagore. Granite in Tavoy and Mergui.

Part 4 (out of print).—Geology of country between Chappar Rift and Harnai in Baluchistan. Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Alumina. Hislopite.

VOL. XXVII, 1894.

Part 1 (out of print).—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.

Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan). Gohna Landslip, Garhwal.

Part 3 (out of print).—Cambrian Formation of Eastern Salt-range. Giridih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn., and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.

Part 4 (out of print).—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistan. Highly Phosphatic Mica Periodotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende-Periodotite in Bengal.

VOL. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Bibliography of Barren Island and Narcondam from 1884 to 1894.

Part 2 (out of print).—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.

Part 3 (out of print).—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.

Part 4 (out of print).—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contact Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyans. Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

VOL. XXIX, 1896.

Part 1 (out of print).—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.

Part 2 (out of print).—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwana-land". Notes.

Part 3.—Igneous Rocks from the Tochi Valley. Notes.

Part 4 (out of print).—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

VOL. XXX, 1897.

Part 1 (out of print).—Annual report for 1896. Norite and associated Basic Dykes and Lava flows in Southern India. Genus Vertebraria. On Glossopteris and Vertebraria.

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